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TECHNIQUE FOR STRUCTURING WILDLIFE GUILDS TO EVALUATE IMPACTS ON WILDLIFE COMMUNITIES

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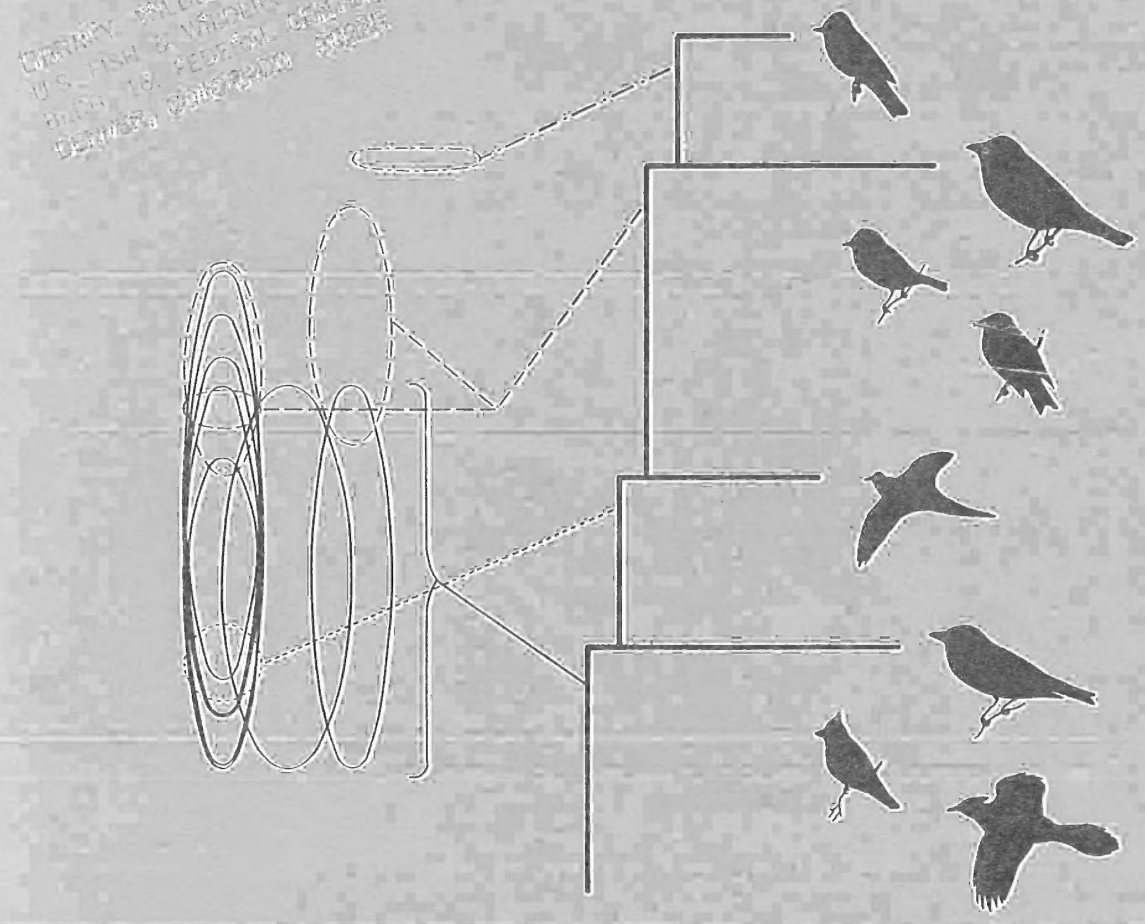

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
Special Scientific Report—Wildlife No. 244

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TECHNIQUE FOR STRUCTURING WILDLIFE GUILDS TO EVALUATE IMPACTS ON WILDLIFE COMMUNITIES

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Technique for Structuring Wildlife Guilds to Evaluate Impacts on Wildlife Communities

by

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Abstract

This paper describes a technique for ordering wildlife information according to physical strata and vegetative structure so that a variety of statistical analyses can be accomplished. Individual wildlife species are assigned to cells in a species-habitat matrix on the basis of feeding and breeding activities within physical strata in representative types of vegetative cover; the cells within the species-habitat matrix are assigned numeric values. The statistical analyses are thus based on the areas that individual species occupy within the species-habitat matrix. Computer graphics are used to represent the structure of wildlife communities and cluster analysis routines are used to describe the potential wildlife guilds that may exist in different vegetative communities. Different numbers of wildlife guilds will occur in different types of cover within a potential natural vegetation type. Furthermore, the number of wildlife species and presumably also of wildlife guilds present within a type of cover is modified by physical attributes of the vegetation within that cover type. The products of this analytical technique may be suitable for evaluating habitat quality, impact assessments, regional inventories and assessments of wildlife resources, and land-use planning activities.

We describe in this paper a technique for relating wildlife species to the structure of vegetative communities so that one can predict the impacts on wildlife communities that will occur as vegetative communities are changed. The technique has a numeric basis so that a variety of computer simulations and analyses can be accomplished to describe wildlife–habitat relationships.

The concepts in this paper were developed with a data base compiled for the eastern ponderosa pine (*Pinus ponderosa*) forest (Küchler 1964, type 16). Data about wildlife species occurring in southeastern Montana and northeastern Wyoming were determined from the literature, were organized according to a species-habitat matrix, and were subjected to statistical analyses. Results of those statistical analyses include graphic illustrations that indicate the dependencies of individual species on the structure of vegetative cover types, and the development of groups of species, called guilds, which utilize similar food sources and breeding niches within habitats for their support and well-being. The structure of wildlife communities that might exist within three different cover types of the eastern ponderosa pine forest type is presented in detail and lists of guilds (and their membership) within each type of cover are described.

Development of our technique has been strongly influenced by the current state of the art for evaluating habitat quality for wildlife, reviewed in detail by Erickson et al. (1980). We have been especially influenced by (1) models that evaluate habitat quality on the basis of the habitat's ability to satisfy life requisite needs of selected animal species, (2) prediction models of wildlife habitat quality that rely on map-based criteria identified from aerial photography, (3) computerized and noncomputerized data bases for wildlife species, and (4) computer simulation models of ecosystem functions.

Our wildlife guilds are aggregations of species that tend to utilize the resources of a habitat in a similar manner. These guilds are closely tied to the structure of vegetation and have a numeric basis so they can be used in habitat simulation and modeling. Thus, if changes in the structure of vegetation can be predicted from some land use, then the probable impacts on wildlife guilds caused by change can also be predicted. In addition, we distinguish between primary and secondary consumer activities for an individual species, if appropriate, so that an omnivorous species can be shown as competing with one group of species as a primary consumer and with a second group of species when acting as a secondary consumer. Our guilds

are less specialized than those advocated by Root (1967) which are associations of species with very similar foraging strategies and habitat requirements. Our guilds, on the other hand, are more specific and meaningful than are artificial classifications or groupings of species based on size, food habits, and foraging strategies (Severinghaus 1981), and seem to provide a greater analytical and predictive capability than does the life form concept of Thomas (1979).

Our guilding technique allows habitat evaluations and assessments to be meaningfully based on a community principle rather than on selected indicator species. Advantages include those of thoroughness and even-handedness in the treatment of all segments of the wildlife community and an enhanced opportunity for interpreting wildlife data with data from other land uses in planning efforts. The potential applications cited in the Discussion section are presumed and not proven. Ongoing research will evaluate the usefulness of the present concepts in natural resource management. Although the analyses, examples, and discussions presented here are directed toward terrestrial communities, the statistical assessments should be equally relevant to aquatic systems.

Six assumptions were made to develop the information presented in this paper:

1. That complex biological requirements of animals can be structured into a two-dimensional matrix, and that energy sources and breeding requirements are so basic that they can meaningfully represent the axes of that matrix.
2. That ordering vegetative cover types into a series of vertical strata is a natural organizational framework within the two-dimensional matrix.
3. That major food sources "of similar importance" can be identified and that these food sources can be organized in a rational manner within the strata of the matrix.
4. That major breeding niches "of similar importance" can be identified and that these breeding niches can be organized in a rational manner within the strata of the matrix.
5. That the biological information about individual species is sufficiently detailed in the literature so that feeding and breeding requirements can be compiled for each wildlife species occurring within a cover type.
6. That the abstract numerical designations given to the food source and breeding niche listings can be subjected to numerical and statistical analyses.

Methods

The development of a technique for translating a variety of descriptive data about wildlife species into a numerical framework was basic to our technology. The biology of any wildlife species is exceedingly complex and many of the biological requirements for any species are poorly known. Simplification of a complex, varied, and poorly known biological universe was obviously required. We selected energy sources and physical breeding requirements as the basis for organizing wildlife information in our guilding analyses. These two criteria are obviously fundamental to the existence of species, are driving forces affecting the behavior of species, and are sufficiently gross parameters so that adequate information might be available for most wildlife species.

We then developed a simple two-dimensional species-habitat matrix with energy sources along the y-axis and physical features of the habitat required for breeding along the x-axis. The y-axis was subdivided so that the lower half of the y-axis could provide loci for data about primary consumers, and the upper half of the y-axis could provide loci for data about secondary consumers. Both axes of the matrix are partitioned by physical strata, because numerous authors have emphasized the importance of strata in describing the form and function of ecological communities. The food sources for animals comprising the y-axis of the matrix are organized as indicated in Fig. 1. The 191 food sources representing the rows of the matrix are identified in Appendix I. The physical features required for breeding (the x-axis of the matrix) are organized as indicated in Fig. 2. The 238 columns representing breeding requirements are identified in Appendix II. The numbers assigned to rows and columns of the matrix are those listed in Appendices I and II.

Feeding and breeding criteria for a species are located in the species-habitat matrix by listing the numeric x and y coordinate values which identify the cell or cells within the general matrix that best describe the habitat requirements of that species. For example, the Steller's jay (see Appendix III for scientific names of vertebrates) occurs in the mature-tree stage of ponderosa pine in the eastern ponderosa pine type of woodland (Küchler 1964, type 16). This jay consumes a variety of insects and herbaceous and pine seeds on the ground and a variety of insects and pine seeds in the pine canopy. Its nest is a bowl of coarse twigs, usually placed in the crotch of a horizontal tree branch within the pine canopy. The x and y coordinates (Appendices I and II) that best describe the requirements of the Steller's jay inhabiting mature ponderosa pine woodlands are listed in Table 1. The data in Table 1 fill the cells in the matrix indicated in Fig. 3.

We have used the concept of potential natural vegetation as a convenient bound for our data sets. The potential vegetation types of Küchler (1964) are areas that presumably produce vegetation of a common taxa and structure if left undisturbed for a sufficiently long period. Presumably the same wildlife community also will eventually develop throughout this type of climax vegetation. The structure of this wildlife community (guilds) could thus potentially be similar throughout this climax vegetation type. These potential guilds can be considered a standard of comparison for the wildlife communities found in current cover types within the potential natural vegetation type. The potential vegetation type is also a useful bound because its area, and the numbers of cover types (current vegetative

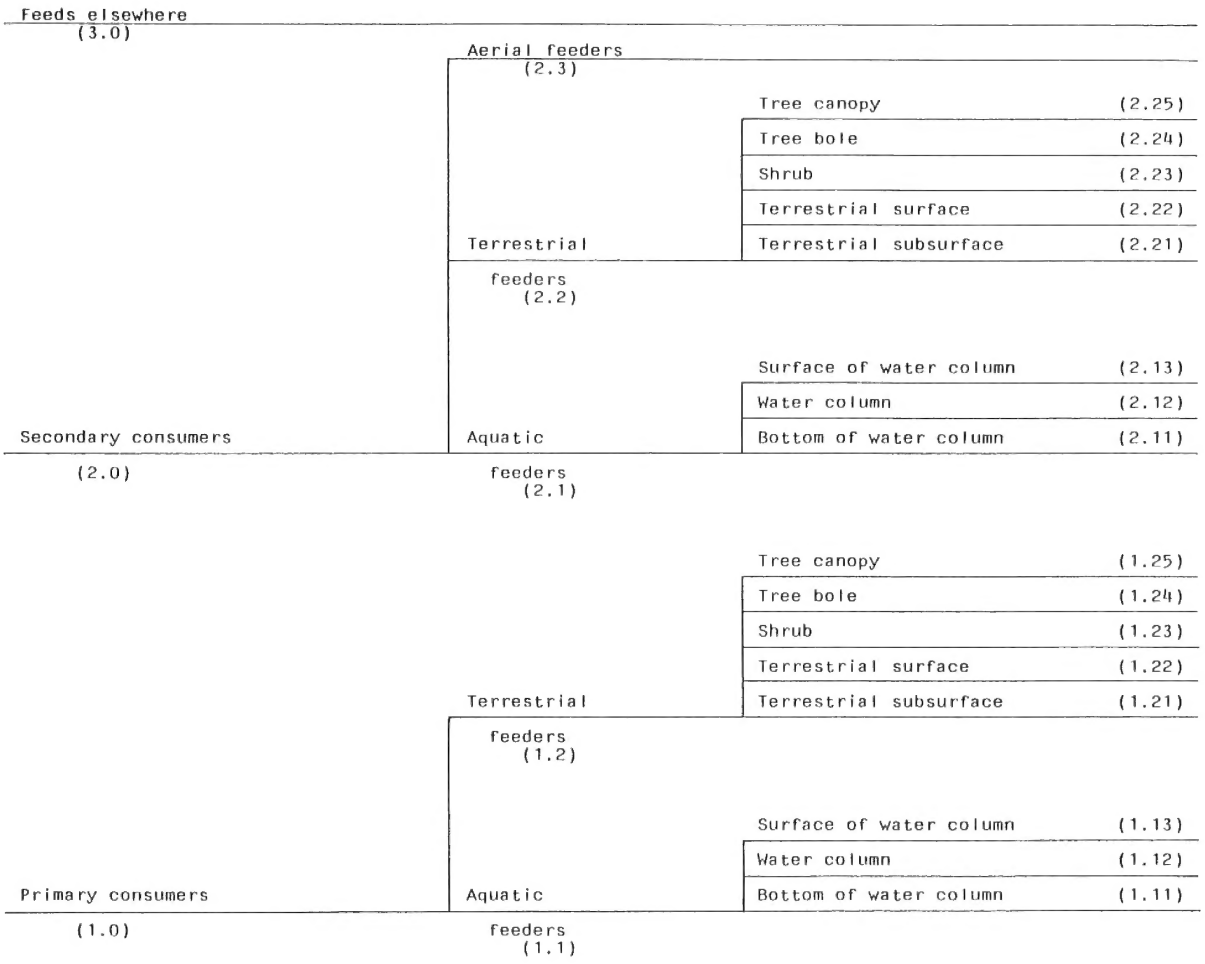

Fig. 1. Organization of food sources by strata along the *y*-axis of the species-habitat matrix.

types) and wildlife species present in those cover types are not unmanageably large.

We developed data sets describing the *x* and *y* coordinates of wildlife species in the climax ponderosa pine type in southeastern Montana and northeastern Wyoming, and also for six additional current vegetation types found in that potential natural vegetation type. Those additional vegetation types are sagebrush steppe (*Artemisia* spp.), upland grassland, riparian grassland, riparian shrubland, riparian woodland, and aspen (*Populus* sp.). Only the data for the upland grassland, sagebrush steppe, and the ponderosa pine type are extensively discussed in the present paper. Data for the other types are included in summary tables. A data base containing the appropriate numeric *x* and *y* coordinates was developed from the literature for each of the 275 nonfish vertebrate species resident and breeding in this potential vegetation type (Appendix III). The numeric data in the data base were structured into a computerized data file, which was then manipulated to produce the various displays and summaries given in the Results section.

Each pair of *x* and *y* coordinates developed for a species in a vegetation cover type represents either a primary consumer or a secondary consumer role. The average *x* and *y* values (and their standard deviations) were calculated for the data describing the primary or secondary consumer role for each species in a data set. These means and standard deviations summarize the feeding and breeding data for each species in that data set. Standard deviations of 0 were listed if only a single *x* and *y* coordinate existed for the primary or secondary consumer role of a species. The means and standard deviations for the data about Steller's jay (Table 1) are also listed in Fig. 3.

Simple and portable computer programs (FORTRAN) were written for checking the basic data, computing the summary statistics, and printing various summaries. The

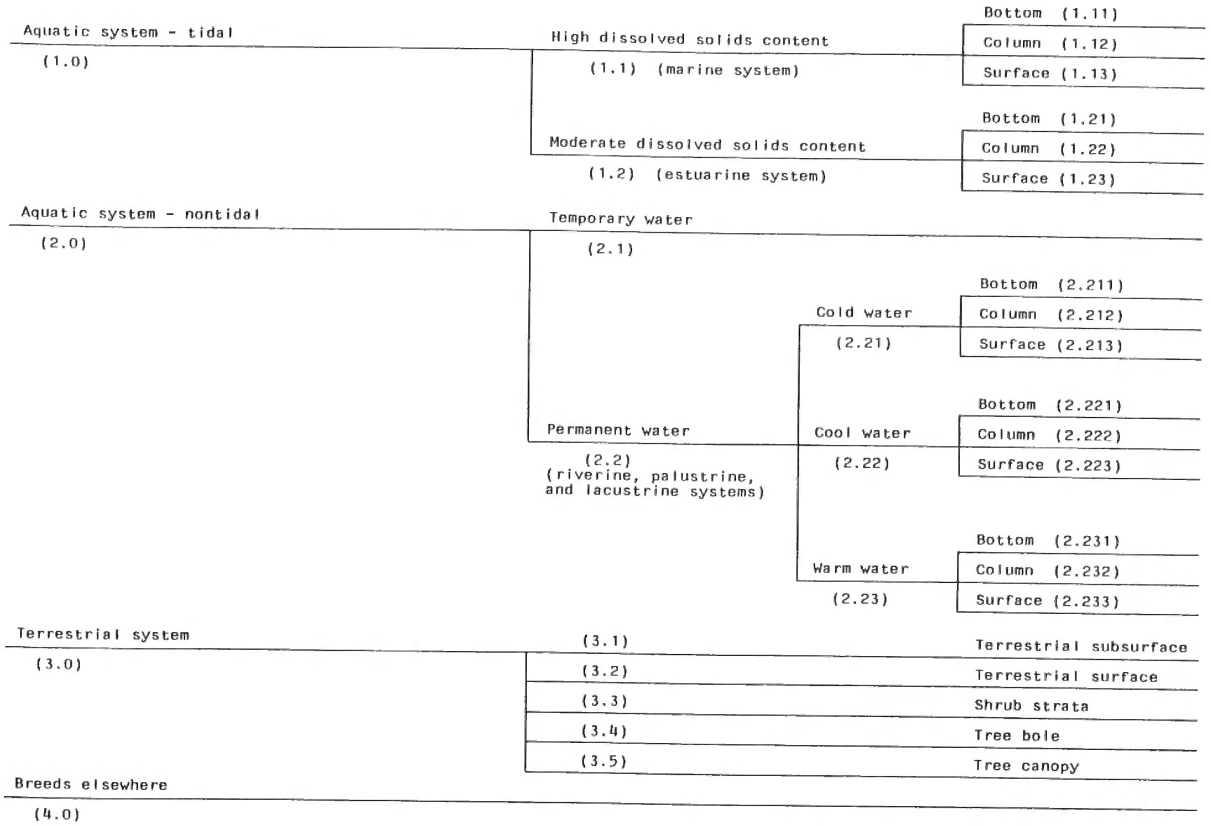

Fig. 2. Organization of breeding habitats by strata along the x-axis of the species-habitat matrix.

data in the species-habitat matrices are displayed in the Results section in a series of plots that graphically depict the increasing complexity of wildlife communities as vertical terrestrial strata are added. These graphics appear as ellipses developed from the summary $\bar{x}$, $\bar{y}$, SD_x, and SD_y data for all species within a habitat. The ellipses are centered on $\bar{x}$, $\bar{y}$ with semi-axis lengths of one standard deviation (SD_x and SD_y). Two ellipse plots for the data in Table 1 are listed in Fig. 3 to describe the position in the species-habitat matrix occupied by Steller's jay. The data describe the jay as both a primary and secondary consumer.

The ellipse plots were created by using CALCOMP graphics software. Only a small driver program (in FORTRAN) was needed to read the summary data files and call the plotting routines. CALCOMP plotting software is available for many computer systems.

The ellipse plot is only one of the possible ways to associate the structure of wildlife communities with that of plant communities. Graphics that indicate the number of species occupying individual cells in the matrix (bar graphs or numerical values) or present this information as a response surface may also be useful in visually transmitting an impression of the structure of a wildlife community.

The summary data ($\bar{x}$, $\bar{y}$, SD_x, and SD_y for primary and secondary consumer roles) were further analyzed with cluster analysis routines to provide a statistical grouping of wildlife species that use similar resources within ecological communities (guilds).

Cluster analysis provides an efficient grouping of species within habitat types and portrays this information as a phenogram (i.e., dendrogram). The formation of phenograms from x,y data is described in the Results section. Everitt (1974) and Sneath and Sokol (1973) provided an introduction to cluster analysis and computer programs for cluster analysis which are widely available. The software package NT/SYS used for these cluster analyses is a system of multivariate statistical programs that was developed by Rohlf et al. (1979), although almost any set of routines for cluster analysis could be used. We used the unweighted pair-group method with arithmetic averages (UPGMA) in conjunction with the euclidean distance between data vectors ($\bar{x}$, $\bar{y}$, SD_x, and SD_y) as the dissimilarity measure, as recommended by Rohlf et al. (1979). This is perhaps the most common cluster method (see Rohlf et al.

Table 1. *The x-y coordinates for feeding and breeding of Steller's jays in the mature-tree stage of ponderosa pine in the eastern ponderosa forest type.*

Consumer	Feeding coordinate y[a]	Breeding coordinate x[b]
Primary consumer	54	229
	54	233
	56	229
	56	233
	57	229
	57	233
	58	229
	58	233
	60	229
	60	233
	85	229
	85	233
Secondary consumer	159	229
	159	233
	181	229
	181	233

[a]Appendix I.
[b]Appendix II.

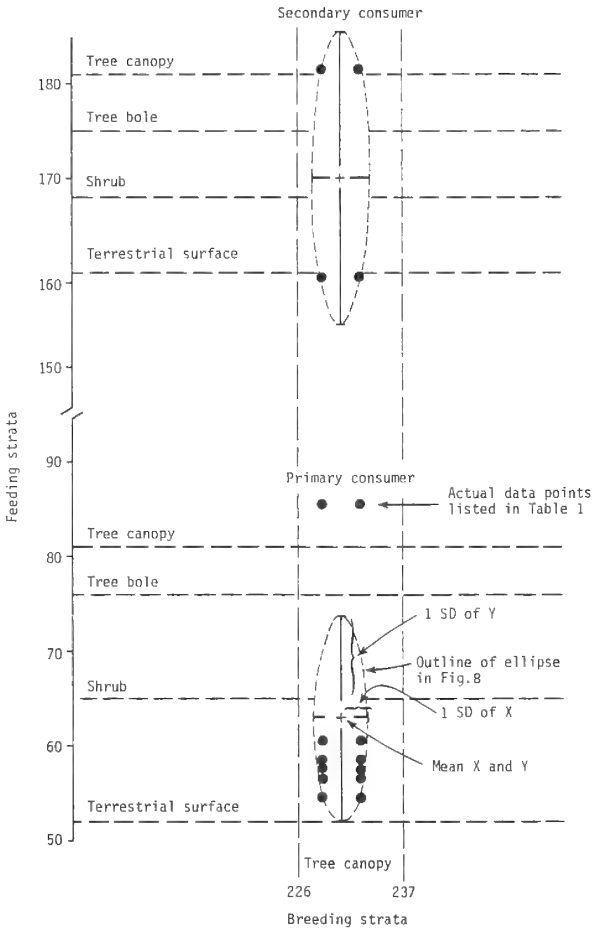

Fig. 3. The x and y coordinate values for Steller's jay (listed in Table 1) and the $\bar{x}$, $\bar{y}$, SD_x, SD_y values for these data are plotted on the species-habitat matrix. The elliptical plots indicating the relative areas occupied by the data within the matrix are also plotted in this figure.

1979:72; Everitt 1974:17, group average method; Sneath and Sokol 1973:124, 230–234).

The cluster analysis program used also computes a "cophenetic" correlation coefficient, R, which is a measure of how faithfully the phenogram (i.e., results of the cluster analysis) represents the information in the original data. It is a way of objectively comparing different clustering results. Sneath and Sokol (1973:278–280) provided information about the cophenetic correlation coefficient.

The y-axis of the species-habitat matrix separates primary and secondary consumers so that guilds from phenograms represent only a single role. About 25% of the guilds (12 of 52) produced when the y-axis was not split into primary and secondary consumer roles contained both primary and secondary consumers (Table 2). This was counter to our intended purpose which was to group into guilds only those species that used the resources of a habitat in approximately the same manner. The occupied cells within the species-habitat matrix, when the y-axis was split, represented sufficiently unique patterns so that wildlife species were aggregated into ecologically meaningful groups. The quality of these guilds (aggregation of species) was not improved (judging from the cophenetic correlation, R) by weighting or distorting average Euclidean distances between groups of species within the matrix by arbitrarily increasing the distance along the x-axis of the matrix by a factor of 2. Calculations with raw or unstandardized data (simple means and standard deviations determined directly from data like that in Table 1) produced guilds whose members shared similar strata blocks with better fidelity than did guilds developed from data that were standardized by a mathematical transformation that produced unit variances for the x and y coordinates for each species. The phenograms and guilds represented in the Results section were therefore developed with unstandardized and unweighted x and y values in the species-habitat matrix.

The x and y coordinate values for wildlife species can be compiled for both the climax vegetation in a potential vegetation type and for the different actual vegetative cover types and their seral stages within a potential vegetative type. The data set that is produced when the x and y coordinate values are compiled for the wildlife species occupying the climax vegetation can be analyzed to describe a potential wildlife community that can then be used as a standard of comparison in habitat evaluation studies. The data sets that are produced when the x and y coordinate values are compiled for actual vegetation types

Table 2. *The effect on guild fidelity of using (1) clumped and divided consumer classes within the species-habitat matrix, (2) scalar multipliers, and (3) standardized and unstandardized data in cluster analysis. Data are for a riparian woodland habitat.*

Treatment	Distance for guild determination	No. of guilds	No. of guilds containing: Both primary and secondary consumers	Inconsistent breeding strata[a]	Inconsistent feeding strata[b]	Both inconsistent feeding and breeding strata	Percent of guilds containing inconsistencies
Clumped consumers (152 species standardized)	0.31	52	12	7	2	2	32.7[c]
Divided consumers (92 primary and 139 secondary)							
Standardized							
Unweighed X	0.36	73	0	2	17	3	30.1
Weighed X	0.52	57	0	2	22	1	43.9
Unstandardized							
Unweighed X	3.6	73	0	6	5	1	16.4
Weighed X	5.2	65	0	3	10	1	21.5

[a]At least one guild member uses breeding strata different from its guild partners.
[b]At least one guild member uses feeding strata different from its guild partners.
[c]Seventeen total guilds with inconsistencies.

within a potential natural vegetation type can be used in impact analysis studies to predict the structure of the wildlife community at a future time when one of those actual vegetation types is hypothesized as the vegetation present at that future time.

The x and y coordinate values for wildlife species occupying a vegetation type could become entries in a computerized data base. A person would determine the structure (guilds) of the wildlife community in a particular vegetation type by (1) obtaining a computer listing of species occurring in that vegetation type, (2) obtaining the x and y coordinates for each species, and (3) subjecting that information to the several statistical analyses described earlier in this section.

Results

Wildlife habitat can be considered in terms of guild blocks. A guild block is formed from a two-dimensional matrix where the y-axis consists of strata where food sources can be found and the x-axis consists of strata where breeding habitats occur. A single guild block is formed from the intersection of a foraging habitat stratum and a breeding habitat stratum. Guild blocks can be thought of as a first approximation of the ways in which wildlife species can utilize a type of habitat. For example, there are nine general ways in which wildlife can utilize the upland grassland habitat. Species can breed (B) in the subsurface stratum and feed (F) in the subsurface stratum; B in the subsurface stratum and F on the surface; B in the subsurface and F in the air; B on the surface and F in the subsurface; B on the surface and F on the surface; B on the surface and F in the air; B elsewhere and F in the subsurface; B elsewhere and F on the surface; and B elsewhere and F in the air. The addition of a shrub stratum in a shrubland community means there are 16 general ways in which wildlife can utilize those habitats. The addition of tree bole and tree canopy strata in a forest suggests that there may be as many as 36 combinations by which wildlife can utilize forests.

The numbers of strata available as wildlife habitat and the numbers of nonfish vertebrates breeding in those habitats increase as the complexity of habitat structure increases from grassland to forest and especially to riparian forest (Fig. 4). Riparian communities may maximize the number of strata available as wildlife habitat within a land section. Riparian communities vary in importance, however, depending on the number of strata actually present. A forest community present in an arid region because of subsurface moisture does not provide as many habitat use combinations for wildlife as does a wetland forest community where aquatic strata are also available.

Information about wildlife communities, organized in even this simplified manner, suggests the impacts that can be expected to occur if land changes affect the structure of vegetation. Spraying of sagebrush and chaining of pinyon–juniper, for example, destroy the structure of vegetative

Surface cover type	Strata									No. of potential breeding species
	BWC	WC	SWC	TSS	TS	SS	TB	TC	Total	
Riparian treeland	0	0	0	0	0	0	●	●	2-8	152
Riparian shrubland	0	0	0	0	0	●			1-6	99
Riparian grassland	0	0	0	0	●				1-5	81
Upland treeland with shrub midstory										
P.pine				●	●	●	●	●	5	124
Aspen				●	●	●	●	●	5	100
Upland treeland with no midstory				●	●		●	●	4	ND
Upland shrubland				●	●	●			3	86
Upland grassland				●	●				2	77
Consolidated substrate (rock)					●				1	ND

Fig. 4. The number of strata available as breeding habitat and the number of vertebrate species potentially breeding in those habitats. Closed circles indicate the strata that are present and open circles indicate additional strata that may be present in different types of surface cover. ND = no data.

communities and act to collapse somewhat complex habitats into the simpler form of grassland habitats. The quality of wildlife habitat in these areas (in terms of the diversity of the total wildlife community that can be supported on an area) is appreciably diminished by such actions.

If the general matrix discussed above is somewhat modified into a species-habitat matrix (Fig. 5), it becomes a useful tool in describing how wildlife species utilize the available strata of habitats. The division of the y-axis allows secondary consumers to be separated from primary consumers so that omnivores can be shown as competing with different species when in their two different consumer roles. We term the guild blocks, when modified to form the species habitat matrix (Fig. 5), "super cells" and base our guilding technology on this concept of super cells.

Species that feed on vegetation on the terrestrial surface and breed in an underground burrow (terrestrial subsurface), for example, would occupy super cell A, identified in Fig. 5. If those species are omnivorous and feed on both vegetation and insects on the terrestrial surface they would occupy super cells A and B in Fig. 5. Super cell A actually consists of 12 rows (Appendix I) and six columns (Appendix II) or 72 individual cells; super cell B consists of 8 rows (Appendix I) and six columns (Appendix II) or 48 individual cells. A variety of species that use different food sources and breeding niches within these loci might thus be clumped within super cells A and B. The primary consumer activities of an omnivorous species may occur in super cells different from those of its secondary consumer activities.

The computer graphics presented in Figs. 6–8 are derived from the four statistical values ($\bar{x}$, $\bar{y}$, SD_x, SD_y) which are developed for each species occurring in a habitat. The graphics in Figs. 6–8 indicate ellipses of various sizes and shapes, representing the position or area each species occupies in the species-habitat matrix for a particular type of vegetation. The x-axis of the ellipse, within a particular type of vegetation, describes a single standard deviation of the one or several columns representing the appropriate breeding-niches for a species (Appendix II); the y-axis of the ellipse describes a single standard deviation of the one or several rows (Appendix I) representing the appropriate energy sources for that species. Although the program producing the computer graphics identifies the individual species described by a particular ellipse, that identification has been removed in Figs. 6–8 to simplify the presentation.

The increasing complexity of wildlife communities, as midstory and overstory strata become available, and

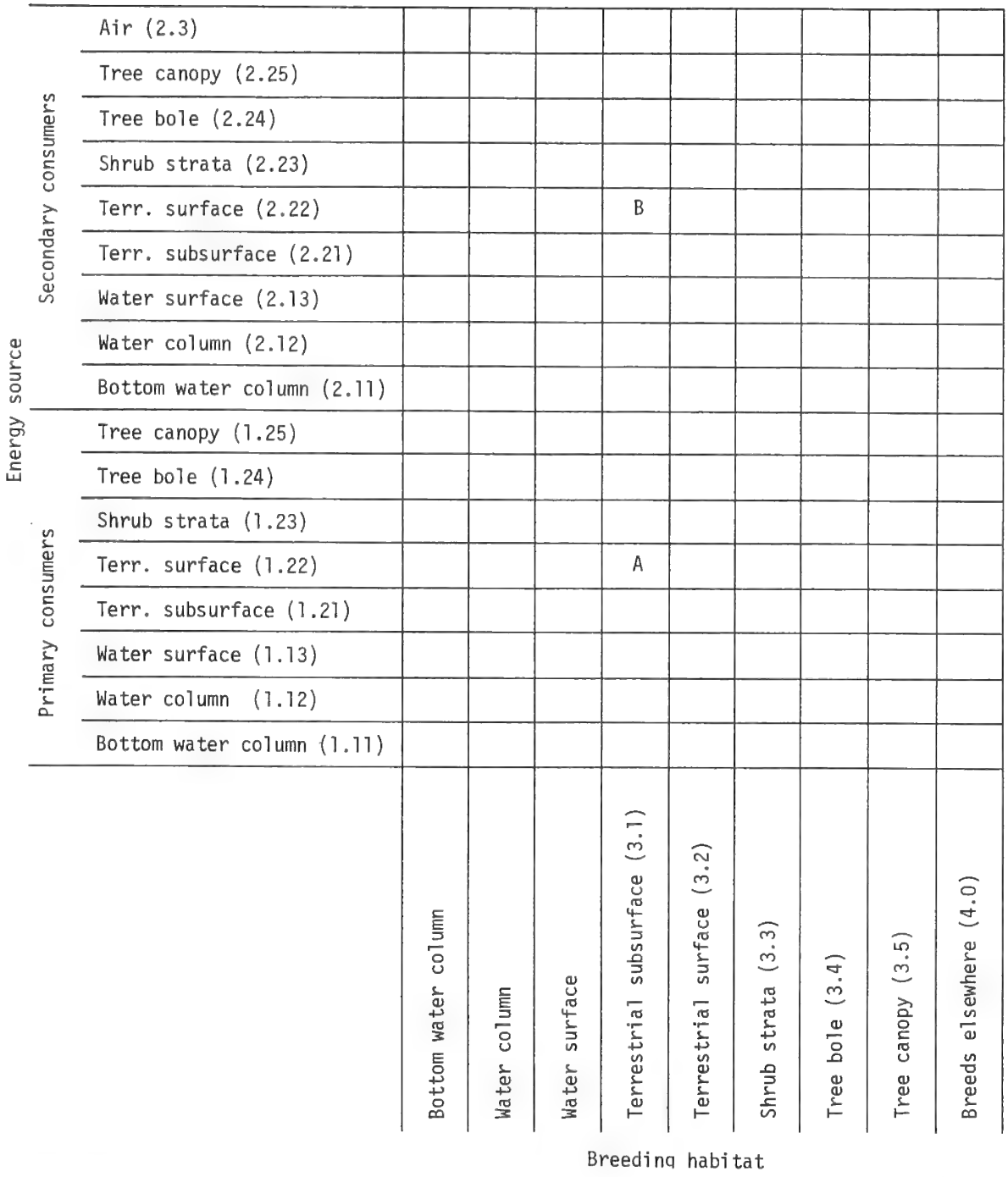

Fig. 5. General appearance of the species-habitat matrix. Wildlife species that feed on vegetative materials on the terrestrial surface and reproduce in burrows or caves occupy super cell A, and wildlife species that feed on animal matter on the terrestrial surface and reproduce in burrows or caves occupy super cell B.

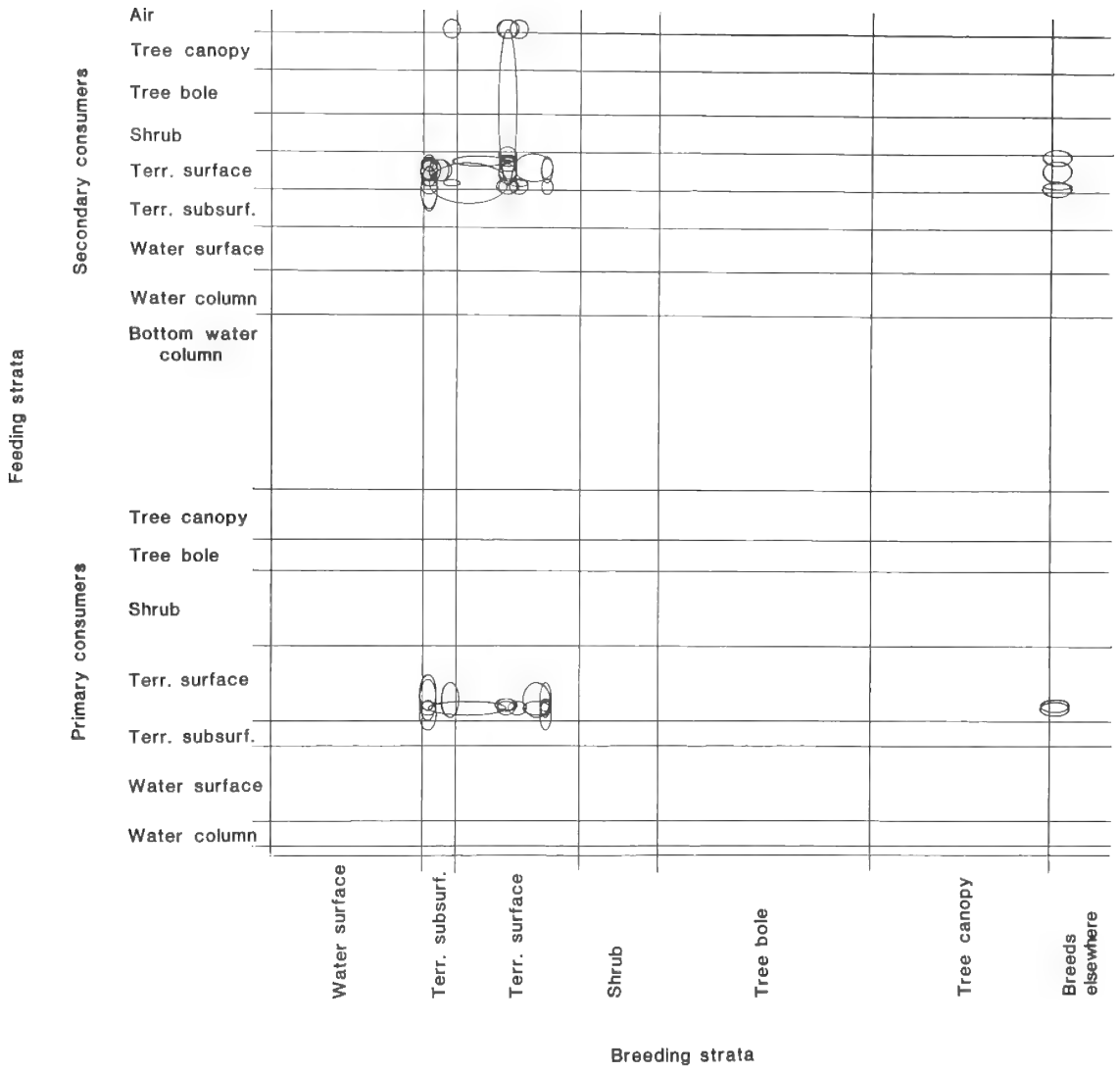

Fig. 6. The positions occupied by individual vertebrate species within the super cells of the species-habitat matrix for upland grassland habitats.

useful habitat is indicated in Figs. 6–8. This increasing complexity is a function of the availability of more strata, the increased number of species occurring in a given habitat, and the fact that some species will use a greater variety of strata when they are available.

The size of an ellipse within a habitat indicates the relative degree of specialization of a species and the shortest axis of the ellipse indicates whether greatest specialization occurs in requirements for breeding or feeding. Species represented by ellipses that are contained within a single habitat stratum can be expected to be adversely impacted by destruction of that stratum and favored by its enhancement. The effects of managing strata on wildlife species can therefore be predicted from the graphics representations. For example, overgrazing on the terrestrial surface stratum, use of phytochemicals in sagebrush eradication, or broad-scale chaining of pinyon–juniper habitats would destroy habitats for species whose ecological requirements are summarized by small ellipses in the terrestrial surface or shrub strata of these respective types of habitat. Strata management, such as the retention of suitable tree boles or snags, may therefore benefit nesting species with requirements for that particular stratum.

Species represented by small ellipses within a single

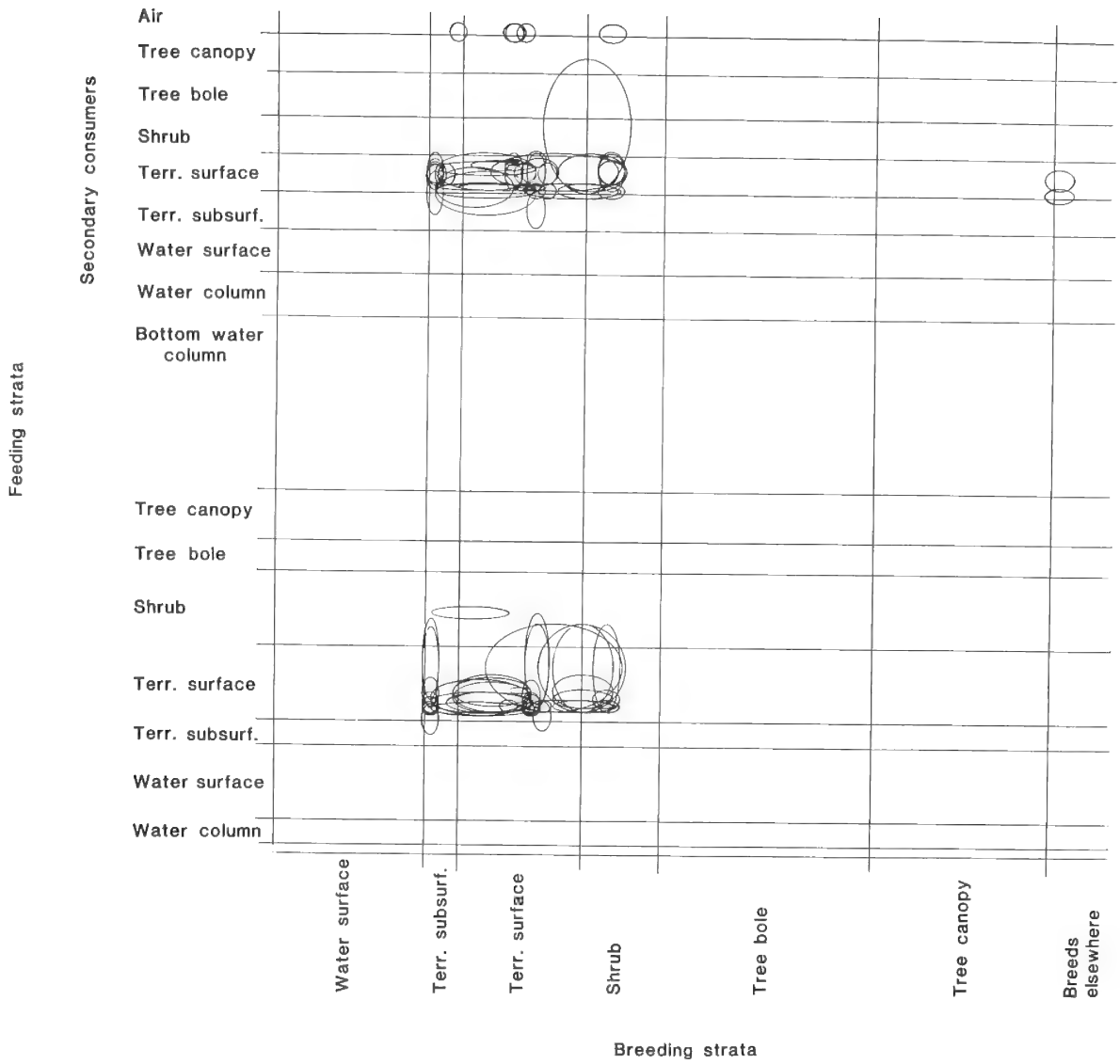

Fig. 7. The positions occupied by individual vertebrate species within the super cells of the species-habitat matrix for upland shrubland habitats.

stratum of habitat, where that stratum or habitat occurs in short supply, should be of special concern to planners and managers. These species may be candidates for threatened or endangered status in the future. Species represented by small ellipses in strata that occur in abundant habitat types would presumably be threatened only if adverse habitat impacts occurred on a wide scale.

The *x-y* coordinates describing the cells in the species-habitat matrix for the mature ponderosa pine community occupied by the Steller's jay are listed in Table 1 and the position of these cells in the species-habitat matrix is indicated in Fig. 3. The cluster analysis routine of Rohlf et al. (1979) develops wildlife guilds from the types of information listed in Table 1 and Fig. 3. Groups of species are clustered together on the basis of the areas (determined by the means and variances of their *x-y* coordinates) each occupies in the species-habitat matrix. A group of species (I) that occupies the same (or nearly the same) group of cells within the species-habitat matrix are clustered together, and species that occupy groups of cells at varying distances from (I) in the matrix are clustered at varying distances from (I). Groups of species within a certain dis-

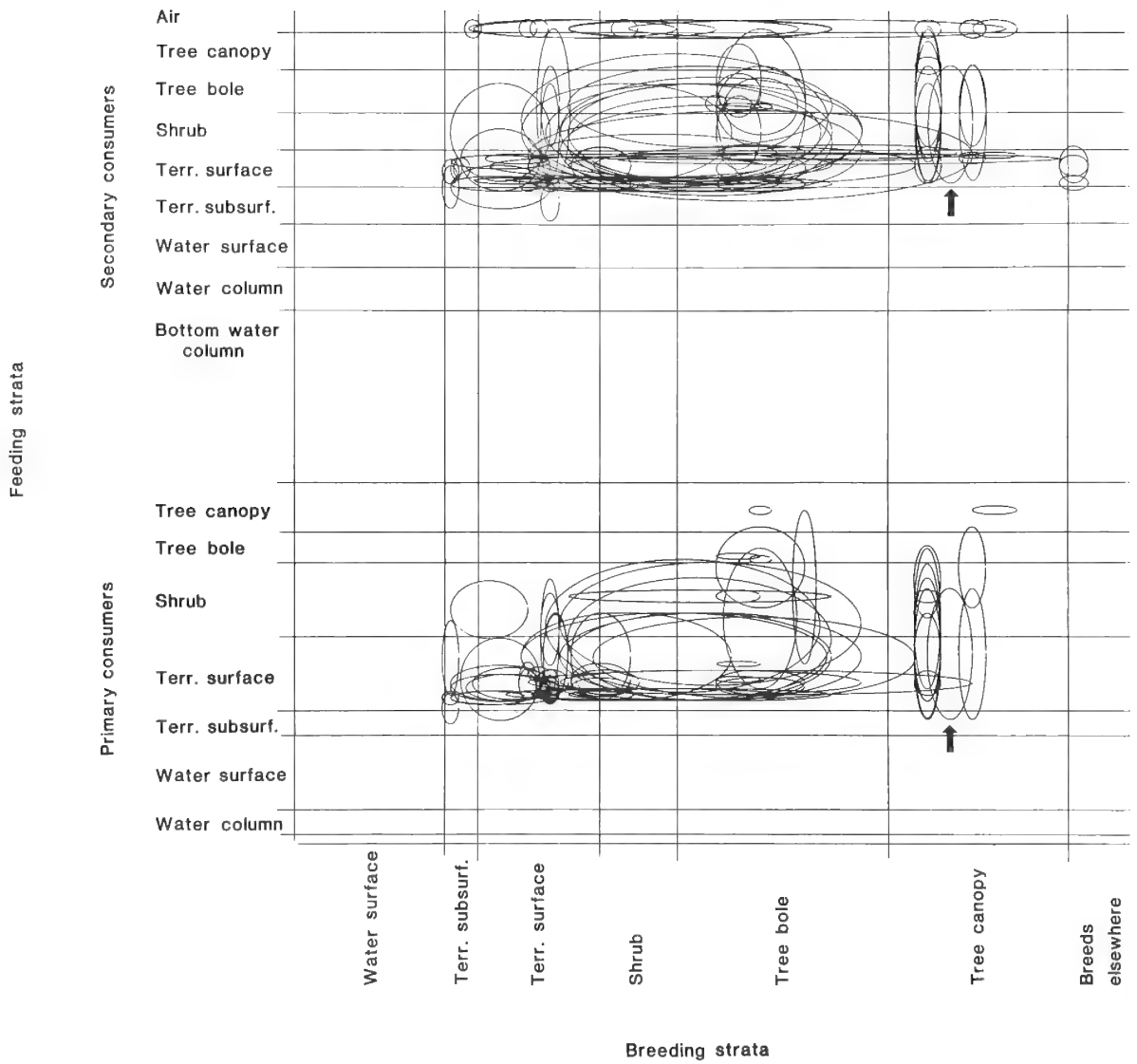

Fig. 8. The positions occupied by individual vertebrate species within the super cells of the species-habitat matrix for upland coniferous woodland habitats. The two ellipses identified by arrows represent the area within the species-habitat matrix occupied by Steller's jay (Table 1).

tance of each other (empirically determined by us not to exceed 3.6 units of Euclidean distance on the x-axis for the phenograms in Figs. 9–11) generally share the same combinations of super cells in fulfilling their breeding and feeding activities.

The splitting of the y-axis in the species-habitat matrix (Fig. 5) causes the cluster analysis routine to produce guilds of species that are either primary or secondary consumers (Figs. 9–11). The use of 3.6 units of Euclidean distance as a determinant for aggregating results from the cluster analysis into wildlife guilds produces groups of species that tend to feed and breed within the same combination of super cells. The relationship between guilds and super cells that results from this mathematical model is strong: the regression equation (Table 3) is $\hat{Y}$ (number of guilds) = 1.13 times (the number of occupied super cells) − 6.24 (r = 0.99).

The actual development of wildlife guilds is illustrated in the following example. The ellipse plots developed for the primary consumers breeding in the tree canopy of a mature ponderosa pine community are represented in Fig. 12. These plots represent a subset of the ellipse plots

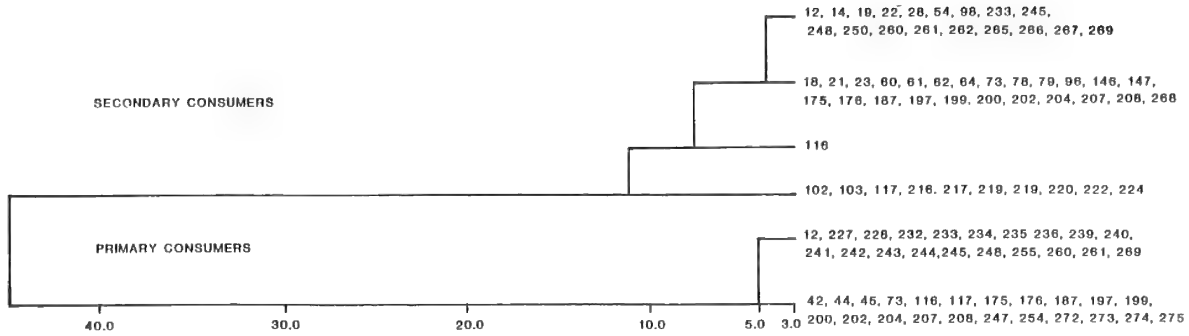

Fig. 9. Phenogram of vertebrate species potentially breeding in upland grassland habitats. *R* value of phenogram = 0.98. The species within the guilds can be identified from Appendix III. Units along abscissa are measures of Euclidean distances.

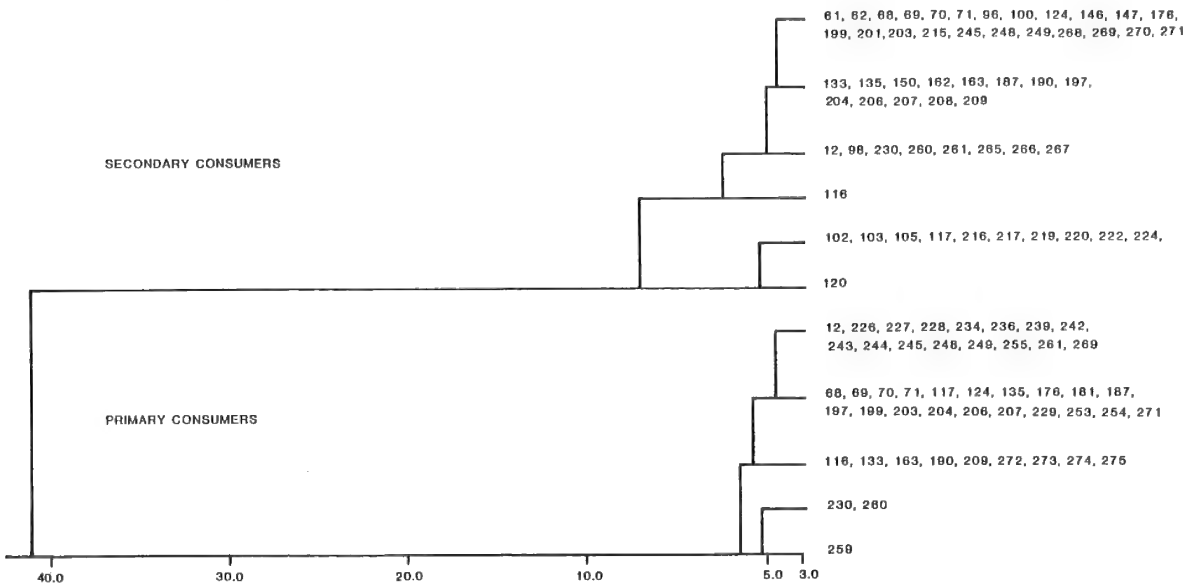

Fig. 10. Phenogram of vertebrate species potentially breeding in upland shrubland habitats. *R* value of phenogram = 0.98.

listed in Fig. 8. The cluster analysis routine disaggregated the 13 data sets represented by the 13 ellipses into the four guilds or groups of wildlife species also indicated in Fig. 12. The four groups of wildlife species represent that fraction of the phenogram or dendrogram distinguished by a bracket in Fig. 11. The four guilds represent groups of wildlife species that share the way they utilize the strata provided by the ponderosa pine woodland as feeding and breeding habitats.

The actual use of super cells for feeding and breeding habitats for all the primary consumers in the ponderosa pine forest is represented in Fig. 13. The letters indicating the positions occupied by each guild in the matrix of Fig. 13 identify the guild in the dendrogram of Fig. 11. The wildlife species represented by the guilds depicted in Figs. 11 and 13 can be identified from Appendix III. Guild R, for example, in Figs. 11, 12, and 13 is composed only of the mourning dove which breeds in the tree canopy and feeds on seeds on the terrestrial surface. Guild S consists of eight species (including the Steller's jay) which breed in the tree canopy and forage on the terrestrial surface, in the shrub strata, and in the tree canopy. This variability in foraging strata is obvious in the large ellipses (large SD_y) for those species evident in Figs. 8 and 12. Guild T in Figs. 11, 12, and 13 consists of the ruby-crowned kinglet, evening grosbeak, and red crossbill which breed in the tree canopy and which forage within the shrub and tree canopies. Guild U in Figs. 11, 12, and 13 is composed only of the western wood peewee which breeds and forages only in the tree canopy. The other 17 groups or guilds of

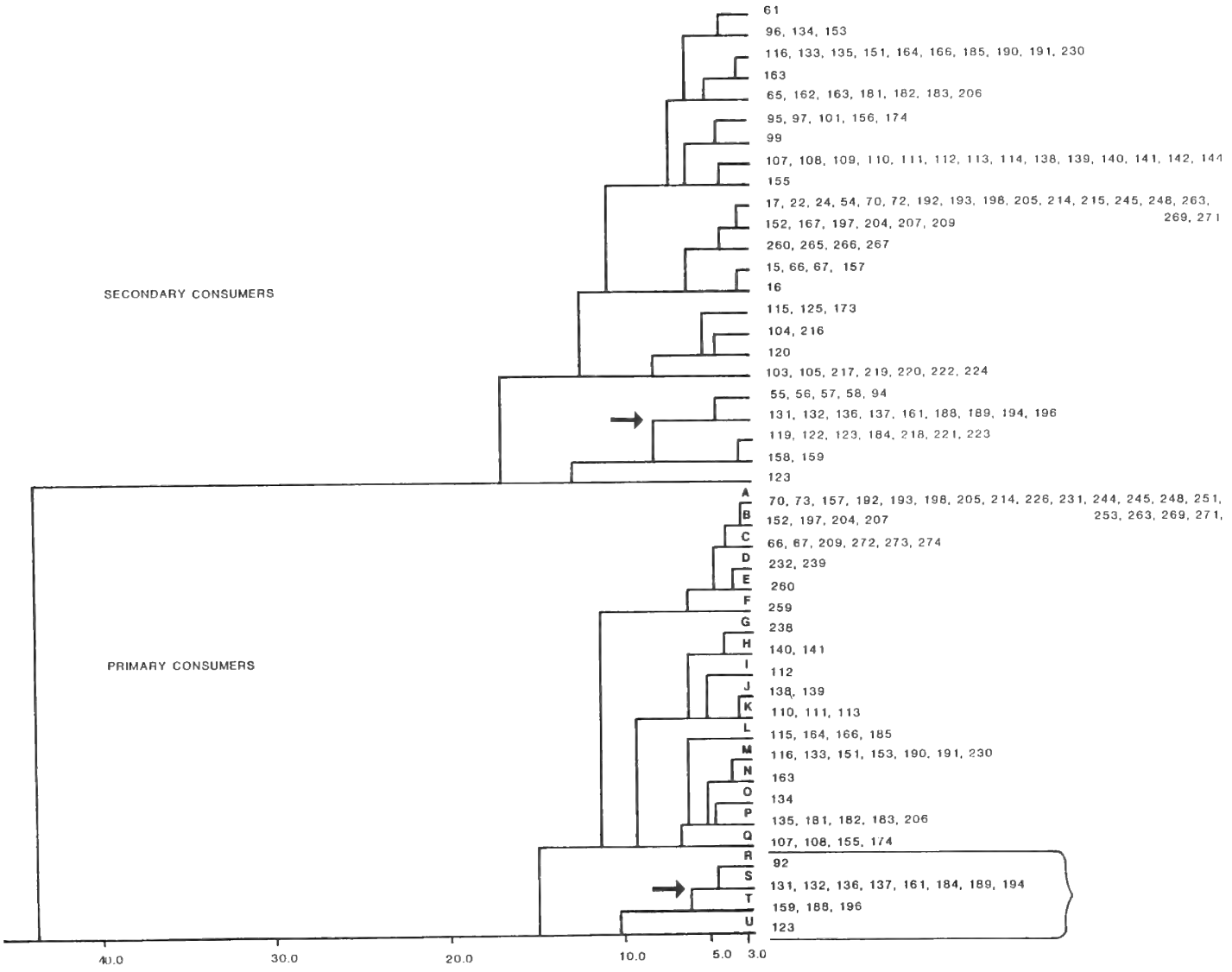

Fig. 11. Phenogram of vertebrate species potentially breeding in upland coniferous woodland habitats. R value of phenogram = 0.96. Steller's jay is a member of each of the two guilds which are identified by arrows (see text for explanation). Units along abscissa are measures of Euclidean distances. Guilds identified by brackets are described in Fig. 12. Guilds identified by letters are listed on Fig. 13.

Table 3. *Relation*[a] *between number of potential breeding species, number of occupied super cells, and number of wildlife guilds in seven habitat types.*

Community type	No. potential breeding species	No. occupied super cells	No. wildlife guilds
Upland grassland	77	9	6
Riparian grassland	81	24	27
Upland shrubland	86	19	11
Riparian shrubland	99	38	32
Upland coniferous woodland (ponderosa pine)	124	44	44
Upland deciduous woodland (aspen)	100	41	39
Riparian woodland	152	68	73

[a]Number of guilds ($\hat{Y}$) = 1.13 (number of super cells) − 6.24, r = 0.99; number of guilds ($\hat{Y}$) = 0.78 (number of breeding species) − 47.43, r = 0.94; number of super cells ($\hat{Y}$) = 0.69 (number of breeding species) − 35.87, r = 0.95.

wildlife species acting as primary consumers and identified by letter in Figs. 11 and 13 also occupy unique combinations of cells within the species-habitat matrix. The seven species comprising Guild M are generalists breeding and feeding in a variety of strata. Guild N represents the ubiquitous starling that occupies a unique combination of strata for foraging and breeding habitat and Guild I is composed of the hairy woodpecker which breeds in the tree bole and feeds in the tree canopy.

The position of the Steller's jay in the dendrogram of Fig. 11 is represented by two arrows. The structure of the primary consumer guild occupied by the Steller's jay has been described above. The Steller's jay also may act as a secondary consumer and in this capacity shares a guild with the gray jay, pinyon jay, Clark's nutcracker, cedar waxwing, evening grosbeak, Cassin's finch, pine siskin, and red crossbill. The nine birds all consume insects and most (except the evening grosbeak and red crossbill) do some foraging for insects on the ground surface. Except for the pinyon jay, all may also forage for insects in the tree canopy (Table 4). Some variability occurs in food habits,

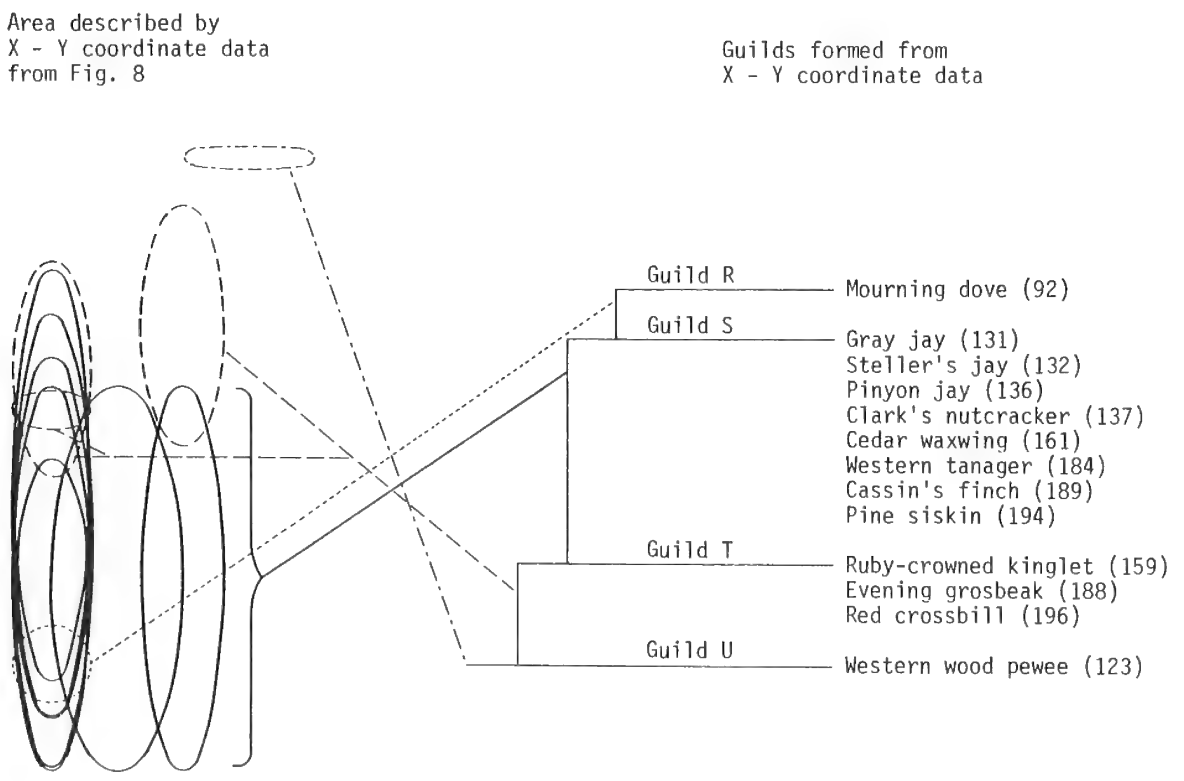

Fig. 12. The ellipse plots correspond to those on Fig. 8 which represent the data for primary consumers that breed in the tree canopy and feed on the terrestrial surface, shrub, tree bole, and tree canopy strata. The cluster analysis routine disaggregates these 13 data sets into the four guilds which are identified by the bracket in Fig. 11.

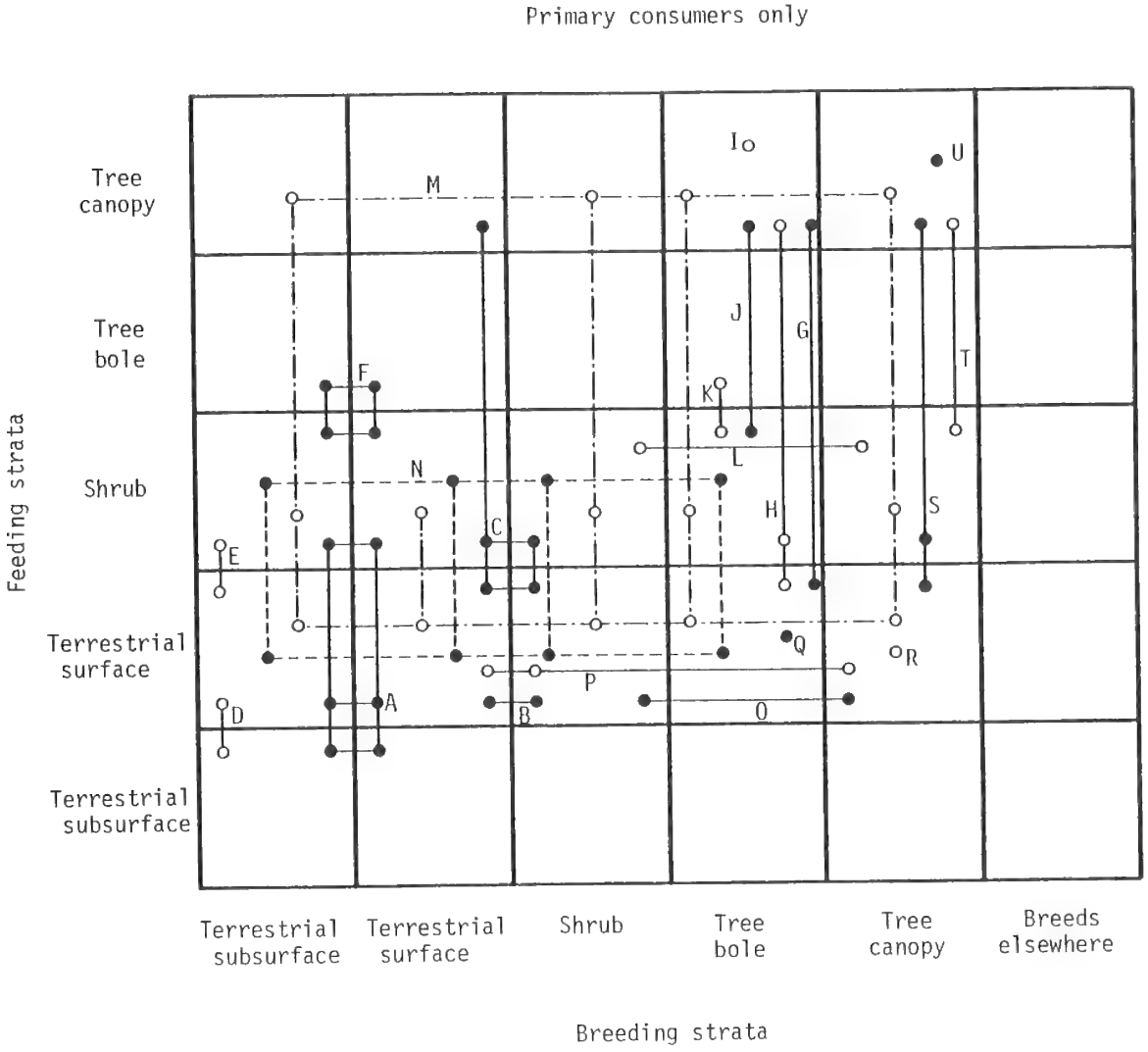

Fig. 13. The guilds of primary consumers indicated in Fig. 11 occupy various combinations of super cells. The letters identifying a guild are also listed on the phenogram in Fig. 11 so both the species forming each guild and the super cells used by each guild can be identified. Different symbols are used to simplify the figure.

however, because the Clark's nutcracker and the gray jay supplement their diets with small mammals and amphibians from the ground surface and with the contents of bird nests found in the tree canopy.

The wildlife guilds defined by the application of cluster analyses possess biological attributes that make the results from the model seem attractive. Species comprising wildlife guilds should be restricted to individual super cells, or similar combinations of super cells, if they are to use environmental resources in a similar manner. The complexity of a biological community in terms of the number of guilds should increase as the number of super cells increases in the habitat. In addition, the close association of wildlife guilds with super cells suggests a basis for predicting impacts on the wildlife community caused by changes in the structure (guild blocks) of vegetative communities. This last generalization is described here.

The structure of the species-habitat matrix suggests that the number of super cells will increase at a geometric rate

Table 4. *Composition of two guilds containing Steller's jay in a community of mature ponderosa pine. All species feed in the tree canopy.*

Vertebrate species[a]	Strata[b] where feeding occurs
Primary Consumer	
Pinyon jay	TS, TC
Cedar waxwing	TS, SS, TC
Cassin's finch	TS, SS, TC
Clark's nutcracker	TS, TC
Gray jay	TS, TC
Steller's jay	TS, TC
Western tanager	TS, SS
Pine siskin	TS, SS, TC
Secondary Consumer	
Pinyon jay	TS
Clark's nutcracker	TS, TB, TC
Cedar waxwing	TS, TC
Gray jay	TS, TC
Steller's jay	TS, TC
Cassin's finch	TS, SS, TC
Pine siskin	TS, SS, TC
Evening grosbeak	SS, TC
Red crossbill	SS, TC

[a]See Appendix III for scientific names.
[b]TS = terrestrial surface, SS = shrub strata, TB = tree bole, TC = tree canopy.

as strata are added to vegetative cover types. Numbers of guilds also seem to increase at a geometric rate, whereas the number of wildlife species increases in a linear manner as strata are added to vegetative cover types (Table 3). The increase in the number of guilds is a function of both the increased opportunities provided by the addition of guild blocks and the increased opportunity for "generalists" that can utilize unique combinations of guild blocks as wildlife habitat. These "generalists" are depicted as "single member guilds" in Figs. 10 and 11. These "generalists" are fairly common in the upland coniferous woodland community (Fig. 11).

Six wildlife guilds were identified for upland grassland (Fig. 9), 11 for the sagebrush steppe (Fig. 10), and 44 as possibly occurring in the ponderosa pine community. Obviously, the number of groups of species that utilize habitat resources in about the same manner increases as the resource opportunities increase with the addition of strata and guild blocks in a habitat. Some of the wildlife guilds identified in Figs. 9–11 and Appendix III may seem to be unlikely guild partners. This guilding technique, however, is intended to link wildlife species with the structure of vegetation and to group species that share dependencies on vegetation of similar structure. These wildlife guilds may include animals from different taxonomic classes and of different biomasses. The animals form a guild if they utilize similar food sources and breeding strategies even though one animal may require grams of a particular plant food, whereas another may require a kilogram of that food. Changes that impact that food will obviously affect both species.

Several techniques have been used to disaggregate groups or guilds of wildlife species to describe particular ecological niches or to describe in detail the unique foraging or reproductive strategies used by a species. Principal Component Analysis (PCA), for example, has been used to determine how guild members actually partition the resources within a guild block. For example, PCA has been used by Anderson and Shugart (1974) to describe the selection of habitat by birds in a deciduous forest in Tennessee, by Rotenberry and Wiens (1980) to determine the effects of vegetation structure on breeding bird populations in steppe habitats of North America, and by Niemi and Pfannmuller (1979) to describe the niche structure for 21 bird species in northeastern Minnesota.

Discussion

The guilding technique is a way to organize and analyze information about wildlife species to provide insight about the structure of wildlife communities under both present and proposed habitat conditions. The development of wildlife guilds provides an excellent model from which to select wildlife species to accomplish a variety of wildlife studies. In addition, wildlife guilds are useful for interpreting the results of inventories and assessments, in performing integrated assessments and management of natural resources, and in forecasting the impact of habitat change on wildlife. Some of these potential applications are described here in detail. The applications are built on two assumptions which are in addition to those six described in the introduction to this paper.

Assumption 7

Guilds of vertebrate animals are, because of the nature of the species-habitat matrix, closely associated with guild blocks. Consequently, it is possible to predict impacts on the wildlife community resulting from changes that will modify the quantity and quality of guild blocks in the vegetative community.

Integrated Management of Renewable Natural Resources

The association of wildlife species with vegetative structure when using the species-habitat matrix provides a common denominator with which other natural resources can be considered in the integrated analyses of natural resources. Fish and wildlife species are associated with various strata in the guilding process and many other natural resource products can also be considered as strata products. For example, strip-mining affects surface and subsurface layers, most agriculture uses the surface strata,

and timber management manipulates the tree bole and tree canopy layers. The impact of various land-management activities on fish and wildlife resources can be predicted from computer simulations that modify energy sources and breeding niches (rows and columns of the species-habitat matrix, Appendices I and II) in the affected strata. Computer simulations can thus display various management options so that development can occur in ways that reduce impacts on wildlife guilds.

Systems Approach for Assessing Wildlife Habitat in the Decision Process

The utility of any habitat evaluation effort is determined by its effectiveness in the decision-making process. The technique described in this paper has relevance to land-use management decision-making because it relates the wildlife community to the structure of vegetative surface cover, which can be controlled through management and predicted through time. This methodology deals with the total wildlife community and can be used to predict changes from established base-line conditions which determine the wildlife guilds present at a specific point in time. Wildlife guilds potentially present in the future can be predicted by establishing species-habitat matrices for the seral stages of surface cover types predicted to be present at those future dates. A comparison of the product of area times guilds times years with base-line conditions represents gains or losses associated with changes in land use and is essentially an assessment of potential impacts.

A conceptual model, developed by Erickson et al. (1980), for assessing wildlife–land-use relationships in the decision-making process is reproduced in Fig. 14. Abiotic, biotic, and human conditions produce the existing wildlife habitat on a site. Areas of different cover types on a development site can be calculated (Table 5) and the guilds that occur in those cover types can be determined. The determination of guilds actually present on a site is made from on-site surveys which provide faunal lists for the different areas of existing wildlife habitat. The species actually present are compared with those species forming the wildlife guilds to determine the guilds actually represented on-site.

Proposed land-use changes will impact the structure of vegetation so that areas of different types of vegetation likely to be present at different time intervals during the life of the proposed project can be predicted (Table 5). The predicted wildlife community (number of guilds) at any time during the project's life can be developed from species-habitat matrices developed for the vegetative types presumed present after development.

The simple calculation of multiplying present hectares by present guilds and future hectares by future guilds (Table 5) illustrates how changes in the total wildlife community can be predicted on the basis of the impacts of proposed land-use options on vegetative surface cover within a land area. These changes can be predicted for a single point in time or for the life of a project.

Assumption 8

Vertebrate species may be present in a habitat if suitable environmental factors, including food sources and breeding niches, are present. The greater the number of suitable environmental factors present in a habitat, up to some point, the greater the potential species richness that may occur in that habitat.

Food sources and breeding niches itemized in Appendices I and II and included in the species-habitat matrix (Fig. 5) are among the most important environmental factors determining the suitability of a habitat for a species. The presence of food sources and breeding niches within guild blocks and the addition of guild blocks to habitat obviously affect species richness. The impact on species richness of modifying food sources (rows) within the species-habitat matrix can be simulated with the data sets used to develop the relationships in Figs. 9–11. For this illustration, the impact of moderate overgrazing is simulated by deleting rows 53–56 and 65–70 (Appendix I) from the computer model. This condition would be realized if essentially all current annual growth in the terrestrial surface strata and in the shrub strata had been removed by grazing. Although representatives of all the potential guilds remain in upland grassland, upland shrub (sagebrush), and upland coniferous woodland (ponderosa pine) habitats, following the simulation, the number of primary consumers in each of the three vegetative types is reduced (Table 6). The specialists requiring herbaceous, forb, or deciduous browse in the surface or shrub strata disappear from these three cover types when the appropriate cells disappear.

Predictive associations can be developed that relate species richness, the total number of vertebrate species on an area, to the number of guild blocks and the structure of vegetation within the strata of different cover types. Such a model is described by Short (1982).

The habitat-gradient model states that of two habitats with the same basic vegetative structure (and thus with the same number of guild blocks), the habitat with greater vegetative density, greater equitability of cover between strata, greater block size, and more persistent vegetation, will have more species and presumably more of the possible guilds that can occur in the habitat type. Thus guilds present on an area within a particular potential vegetation type can be used as an assessment of habitat quality. The habitat-gradient model neither predicts the individual species likely to be present nor the actual guild structure of the community likely to occur on that habitat. Identification of individual species occurring on a site is a product of animal inventory information. A comparison of animals found on a site with lists of species constituting potential guilds for that habitat type is the best way to determine the actual guilds occurring in an area.

The habitat-gradient model can also be derived from interpreted aerial photography (Short 1982). An area to be characterized is first subjected to an on-site evaluation to

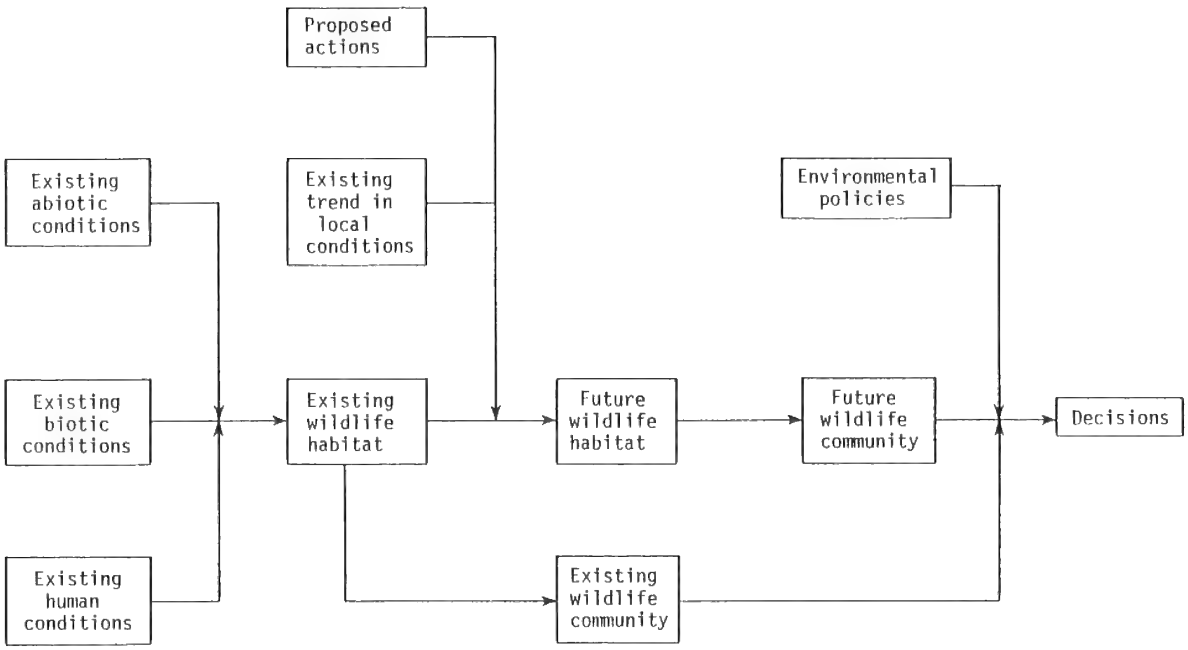

Fig. 14. A systems approach to the assessment of wildlife–land-use relations and the decision-making process (after Erickson et al. 1980).

Table 5. *Calculation of predicted change in the wildlife community caused by modification of vegetation cover types resulting from proposed land-use actions.*

	Hectares in block		Guilds in habitat		Community comparison	
Polygon cover type	Present	Proposed	Present	Proposed	Present guilds × hectares	Proposed guilds × hectares
A	200		30		6,000	
B	500	300	20	20	10,000	6,000
C	100		15		1,500	
D	100		12		1,200	
E	100		10		1,000	
F		700		15		10,500
Total					19,700	16,500

Change in composition and size of wildlife community associated with land use change = 19,700 – 16,500/19,700 = 16.2% = the potential reduction in wildlife values.

Table 6. *Impacts of heavy grazing on guilds and number of primary consumers in three types of upland vegetative cover.*

	Nongrazed condition		Heavily grazed condition	
Vegetation cover type	No. of potential guilds	Total no. primary consumers	No. of potential guilds present	Total no. primary consumers
Upland grassland	2[a]	42	2	12
Upland shrubland	6	48	6	33
Upland coniferous woodland	21	76	21	66

[a]Impact is calculated only for guilds of primary consumers.

develop prediction equations between overstory density and the density of cover in the midstory and understory. Aerial photographs are then differentiated into polygons on the basis of the structure and density of the overstory so that, using the prediction equations, a representation of the vertical profile of each polygon is formed. A habitat characterization value is then developed for each polygon using the same structural parameters (number of guild blocks, vegetative density, equitability of cover between strata, etc.) used in predicting species-richness from on-site assessments. The habitat characterization value of a polygon multiplied by the area of that polygon and summed for all the polygons within the area being characterized represents the numerator of a ratio whose denominator is the maximum characterization value that can be expected within that potential natural vegetation type. The greater the ratio, the greater the presumed species-richness in the area and the greater the presumed area × guilds value for the characterized area.

Habitat evaluation using guilds is a measure of total guilds that have members which apparently find a piece of land to be adequate habitat. This type of analysis allows the animal to determine whether a habitat adequately provides for its life requirements. The analysis does not determine how adequate the habitat is for a particular species, nor does it determine whether nonhabitat-related factors are responsible for the absence of a species from an area. The assumption is that a member of a wildlife guild will be present in a habitat if that habitat provides suitable life requirements for a guild member. If the first of two pieces of land, with the same possible guild structure, sustains representative species of only 25% of the guilds that can occur in that vegetative community, then that land is of lesser quality to the total wildlife community than is the second piece of land sustaining representatives of 75% of the guilds that can occur in that vegetative community.

Lists of guilds found on an area in a particular vegetative type can be compared with lists of guilds that can theoretically occur in that potential vegetation type. The determination of why guilds are apparently missing from an area can be a diagnostic exercise. Is a guild missing because of some structural deficiency (affecting food sources and breeding niches) in a guild block? Can some remedial management practice be exercised to correct structural deficiencies so that habitat for particular guilds can be enhanced?

The Habitat Evaluation Procedures (HEP; U.S. Fish and Wildlife Service 1980) will accept a measurement of habitat suitability that is a ratio of guilds observed in a cover type divided by the numbers of guilds that can occur in that potential vegetative type. The bound of potential vegetation thus provides a standard of comparison for all those cover types within a potential vegetation type. The habitat suitability value provides a measure of habitat quality for base-line conditions. For future conditions, predicted wildlife guilds can be simulated from data developed from the species-habitat matrices for the vegetative cover types hypothesized present at some future time, t. The denominator to determine future habitat quality remains the same because the potential natural vegetation remains the same. The numerator at time t is determined from the guilds predicted present at t. Predicted guilds are determined from the presumed vegetative cover type and its structure at time t. The simulation to determine the wildlife community present at t may include any modifications to strata, and rows and columns within strata, for the species-habitat matrix describing the cover type presumed present at time t. Multiple future conditions can be simulated for the decision-maker, to determine the effects of different management options on habitat quality at time t. The ratio developed from predicted guilds and the standard of comparison produces a measure of future habitat quality.

The advantages of using the guilding technique in HEP are that guilding provides a measure of habitat quality pertinent to the total wildlife community on an area, and that simple faunal surveys can provide the field data for determining base-line habitat quality.

Conclusions

We have described a technique for associating wildlife species with the structure of wildlife habitat so a variety of computerized analyses can occur to help predict impacts on wildlife caused by changes in the structure of habitat. The concepts developed in this paper were developed with a data base formulated for 275 wildlife species occurring in the eastern ponderosa pine type of forest (Küchler 1964, type 16) in southeastern Montana and northeastern Wyoming. Our technique is based on the assumption that a wildlife species can be categorized as occupying a discrete area within a two-dimensional "species-habitat" matrix. Food sources and breeding niche requirements make up the two axes of the species-habitat matrix and numeric values identify the cells representing the food sources and breeding niche requirements necessary for each wildlife species. A variety of statistical analyses can be accomplished on the areas (combinations of cells) occupied by different wildlife species so that a description of the structure of the wildlife community within a habitat type can be developed. The assumptions made in the development of the species-habitat matrix are included in the text.

The models produced in the present study indicate that (1) the species-habitat matrix provides a useful way to order wildlife information, (2) the statistical analyses provide a structuring of the wildlife community that is biologically reasonable, and (3) a variety of management needs are served in a unique way because the analyses pertain to the total wildlife community. In particular, the computer graphics illustrate, as expected, the complexity of the wildlife community that can occur as guild blocks are added to surface cover, and results from the cluster analyses describe, as expected, the increase in numbers of

wildlife guilds that occur as guild blocks are added to wildlife habitat.

The greatest difficulties in working with our guilding technique are associated with developing the data base to drive the guild analyses. Difficulties occur because wildlife species have not historically been associated with vertical strata in the environment (an important subdivision within the species-habitat matrix). We believe this is an imprecision in the quality of natural history information (field biologists have not historically associated species with strata), rather than a flaw in the design of the species-habitat matrix. The correct positioning of wildlife species within vertical strata requires expert judgment even though food habit and breeding niche requirements are among the best known information about individual species. A second problem encountered in building the data base is the determination of "normal" and "abnormal" food habits and breeding activities. We consider "abnormal" feeding and breeding information to be those exceptions that are so unusual and occur so rarely as to be noteworthy events. Such noteworthy events are not considered in the development of the species data base.

The suggested application of the principles determined from the guilding model is presumed and not proven. The determination of the utility of the proposed applications must wait until an applications study, presently under way, is completed. Still we can conclude that the ability to associate wildlife guilds with the structure of habitat allows good predictions to be made about the impacts of habitat change on the structure of the wildlife community, and that wildlife guilds actually occupying an area compared with the standard guild structure that can occupy an area may possibly be a useful measure of habitat quality. This measure compares the structure of the actual wildlife community with the structure of the wildlife community that would potentially occupy the area. The standard guild structure is determined for the climax community of the potential natural vegetation that can occur on an area and the actual guilds present on the area are determined by comparing species found on an area with lists of species comprising the guilds that can occur on the area. An additional utility of the guilding technique is that the structure of the wildlife community present at some future time can be simulated if the structure of the vegetation community present at the future time can be hypothesized. This capability should enhance the assessment of impacts of habitat change on the wildlife community.

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Appendix I

Y-coordinate Numbers (Left-hand Column) and the Corresponding Food Source by Strata (Right-hand Column) Used in the Determination of Wildlife Guilds

1.0 **Primary Consumers**

1.1 Feeds on vegetation in aquatic systems

1.11 Feeds on vegetation at bottom of water column (substrates are under water columns >25 cm deep)

Natural reef

001	Detritus (organic)
002	Plankton
003	Diatoms (encrusting on bottom substrate)
004	Filamentous algae
005	Rooted vascular plants
006	Other (e.g., parts of terrestrial rooted plants)

Artificial reef (man-made structure)

007	Detritus (organic)
008	Plankton
009	Diatoms (encrusting on bottom substrate)
010	Filamentous algae
011	Rooted vascular plants
012	Other (e.g., parts of terrestrial rooted plants)

Consolidated bottom

013	Detritus (organic)
014	Plankton
015	Diatoms (encrusting on bottom substrate)
016	Filamentous algae
017	Rooted vascular plants
018	Other (e.g., parts of terrestrial rooted plants)

Unconsolidated bottom

019	Detritus (organic)
020	Plankton
021	Diatoms (encrusting on bottom substrate)
022	Filamentous algae
023	Rooted vascular plants
024	Other (e.g., parts of terrestrial rooted plants)

Aquatic bed

025	Detritus (organic)
026	Plankton
027	Diatoms (encrusting on bottom substrate)
028	Filamentous algae
029	Rooted vascular plants
030	Other (e.g., parts of terrestrial rooted plants)

1.12 Feeds on vegetation within water column (i.e., vegetation in water >25 cm below the surface)

031	Detritus (organic)
032	Plankton
033	Diatoms (encrusting on protruberances)
034	Filamentous algae (extending into column)
035	Rooted vascular plants (extending into column)
036	Other (e.g., parts of terrestrial rooted plants)

1.13 Feeds on vegetation at surface of water column (includes vegetation at shoreline or under shallow water [≤25 cm deep], in open water [≤25 cm deep], and on vegetation extending up to or through surface waters)

037	Detritus (organic)
038	Plankton
039	Diatoms (encrusting on protruberances)
040	Filamentous algae
041	Floating vascular plants
042	Rooted herbaceous vascular plants (at surface)
043	Rooted woody vascular plants (at surface)
044	Rooted herbaceous vascular plants (through surface)
045	Rooted woody vascular plants (through surface)
046	Moss (at water–land interface)
047	Other (e.g., parts of terrestrial woody plants)

1.2 Feeds on vegetation in terrestrial systems

1.21 Terrestrial subsurface (to 10 cm below apparent surface)

048	Fungi
049	Roots, tubers, and rhizomes of herbaceous plants
050	Roots, tubers, and rhizomes of woody plants
051	Other plant materials

1.22 Terrestrial surface (from 10 cm below apparent surface to 0.5 m above apparent surface)

052	Fungi
053	Grass and grasslike leaves and stems (including rootstock)
054	Grass and grasslike flowers and fruits
055	Forb leaves and stems (including rootstock)
056	Forb flowers and fruits
057	Deciduous shrub leaves and fruit (seeds) on ground (and leaves and fruit of deciduous supine shrubs)
058	Evergreen shrub leaves and fruit (seeds) on ground (and leaves and fruit of evergreen supine shrubs)
059	Deciduous tree leaves and fruit (seeds) on ground
060	Evergreen tree leaves and fruit (seeds) on ground
061	Roots, twigs, and bark of woody stems (extending into higher strata)
062	Cactus stems and pads
063	Cactus flowers and fruit

1.23 Shrub strata (from 0.5 to 8.0 m above apparent surface)

064	Fungi
065	Grass and grasslike leaves and stems (extending into shrub strata)
066	Grass and grasslike flowers and fruit (extending into shrub strata)
067	Forb leaves and stems (extending into shrub strata)
068	Forb flowers and fruit (extending into shrub strata)
069	Leaves and twigs (including cambium) of deciduous woody shrubs
070	Flowers and fruit of deciduous woody shrubs
071	Leaves and twigs (including cambium) of evergreen woody shrubs
072	Flowers and fruit of evergreen woody shrubs
073	Parasitic or epiphytic plants
074	Cactus stems and pads
075	Cactus flowers and fruit

1.24 Tree boles

076	Fungi
077	Tree sap
078	Tree cambium
079	Cactus stems and pads
080	Cactus flowers and fruit

1.25 Tree canopy

081	Fungi
082	Leaves and twigs of deciduous trees
083	Flowers, fruits, and seeds of deciduous trees
084	Leaves and twigs of evergreen trees
085	Flowers, fruits, and seeds of evergreen trees
086	Leaves and twigs of lianas
087	Flowers, fruits, and seeds of lianas
088	Parts from parasitic or epiphytic plants

2.0 **Secondary Consumers**

2.1 Feeds on animal matter in aquatic systems

2.11 Feeds on animal matter at bottom of water columns (substrates are under water columns >25 cm deep)

Natural reef

089	Zooplankton
090	Arthropods
091	Other invertebrates (includes mollusks)
092	Fish (eggs, fry, adults)
093	Amphibians (eggs, juveniles, adults)
094	Reptiles (eggs, juveniles, adults)
095	Birds
096	Mammals
097	Scavenger (carrion)

Artificial reef (man-made structure)

098	Zooplankton
099	Arthropods
100	Other invertebrates (includes mollusks)
101	Fish (eggs, fry, adults)
102	Amphibians (eggs, juveniles, adults)
103	Reptiles (eggs, juveniles, adults)
104	Birds
105	Mammals
106	Scavenger (carrion)

Consolidated bottom

107	Zooplankton
108	Arthropods
109	Other invertebrates (includes mollusks)
110	Fish (eggs, fry, adults)
111	Amphibians (eggs, juveniles, adults)
112	Reptiles (eggs, juveniles, adults)
113	Birds
114	Mammals
115	Scavenger (carrion)

Unconsolidated bottom

116	Zooplankton
117	Arthropods
118	Other invertebrates (includes mollusks)
119	Fish (eggs, fry, adults)
120	Amphibians (eggs, juveniles, adults)
121	Reptiles (eggs, juveniles, adults)
122	Birds
123	Mammals
124	Scavenger (carrion)

Aquatic bed

125 Zooplankton
126 Arthropods
127 Other invertebrates (includes mollusks)
128 Fish (eggs, fry, adults)
129 Amphibians (eggs, juveniles, adults)
130 Reptiles (eggs, juveniles, adults)
131 Birds
132 Mammals
133 Scavenger (carrion)

2.12 Feeds on animal matter within water column (i.e., on animal matter in water >25 cm below the surface)

134 Zooplankton
135 Arthropods
136 Other invertebrates
137 Fish (eggs, fry, adults)
138 Amphibians (eggs, juveniles, adults)
139 Reptiles (eggs, juveniles, adults)
140 Birds
141 Mammals
142 Scavenger (carrion)

2.13 Feeds on animal matter at surface of water column (includes animal matter at shoreline or under shallow water [≤25 cm deep], in open water [≤25 cm deep], and on vegetation extending up to or through surface waters)

143 Zooplankton
144 Arthropods
145 Other invertebrates
146 Fish (eggs, fry, adults)
147 Amphibians (eggs, juveniles, adults)
148 Reptiles (eggs, juveniles, adults)
149 Birds
150 Mammals
151 Scavenger (carrion)

2.2 Feeds on animal matter in terrestrial systems

2.21 Terrestrial subsurface (to 10 cm below apparent surface)

152 Arthropods
153 Other invertebrates
154 Amphibians (juveniles, adults)
155 Reptiles (eggs, juveniles, adults)
156 Birds (eggs, nestlings, adults)
157 Mammals (nestlings, adults)
158 Scavenger (carrion)

2.22 Terrestrial surface (from 10 cm below apparent surface to 0.5 m above apparent surface)

159 Arthropods
160 Other invertebrates
161 Amphibians (juveniles, adults)
162 Reptiles (eggs, juveniles, adults)
163 Birds (eggs, nestlings, adults)
164 Mammals, small (≤1 kg; young, adults)
165 Mammals, large (>1 kg; young, adults)
166 Scavenger (carrion)

2.23 Shrub strata (from 0.5 to 8.0 m above apparent surface)

167	Arthropods
168	Other invertebrates
169	Amphibians (juveniles, adults)
170	Reptiles (juveniles, adults)
171	Birds (eggs, nestlings, adults)
172	Mammals
173	Scavenger (carrion)

2.24 Tree boles

174	Arthropods
175	Other invertebrates
176	Amphibians (juveniles, adults)
177	Reptiles (juveniles, adults)
178	Birds (eggs, nestlings, adults)
179	Mammals
180	Scavenger (carrion)

2.25 Tree canopy

181	Arthropods
182	Other invertebrates
183	Amphibians (juveniles, adults)
184	Reptiles (juveniles, adults)
185	Birds (eggs, nestlings, adults)
186	Mammals
187	Scavenger (carrion)

2.3 Feeds on animal matter in the air above any aquatic surface or above any terrestrial strata

188	Arthropods
189	Birds
190	Mammals

3.0 **Feeds Elsewhere**

191	Vertebrates that breed in one or more columns (*x*-axis) in a habitat type but do not feed in that habitat type

Appendix II

X-coordinate Numbers (Left-hand Column) and the Corresponding Breeding Niches by Strata (Right-hand Column) used in the Determination of Wildlife Guilds

1.0 Tidal (marine and estuarine systems)

1.1 Water typically contains a high dissolved solid (>30 ppt) content

Bottom of water column (include substrates under water columns >25 cm deep)

001	Corral reef
002	Worm reef
003	Mollusk reef
004	Man-made structure (artificial reef)
005	Bedrock (solid rock mass)
006	Boulder (>305 mm)
007	Rubble (152–305 mm)
008	Cobble (64–152 mm)
009	Gravel (2–64 mm)
010	Sand (0.063–2 mm)
011	Mud (<0.063 mm) or organic matter (detritus or sapropel)
012	Submerged algae or moss
013	Submerged rooted vascular plants

Water column (water >25 cm below the surface)

014	Water shallow (<2 m)
015	Water deep (>2 m)

Surface of water column (includes substrates and vegetative cover at shoreline or under shallow water [≤25 cm deep], open water [≤25 cm deep], and types of vegetation extending up to or through surface waters)

016	Artificial (man-made) structures
017	Bedrock (solid rock mass)
018	Boulder (>305 mm)
019	Rubble (152–305 mm)
020	Cobble (64–152 mm)
021	Gravel (2–64 mm)
022	Sand (0.063–2 mm)
023	Mud (<0.063 mm) or organic matter (detritus or sapropel)
024	Aquatic bed—algae, moss, or lichen
025	Rooted herbaceous vegetation
026	Rooted woody vegetation
027	Open water
028	Floating filamentous algae (non-rooted and rooted)
029	Floating non-woody vascular plants (non-rooted)
030	Floating non-woody vascular plants (rooted)
031	Floating woody vascular plants (non-rooted)
032	Floating woody vascular plants (rooted)
033	Emergent non-woody vascular plants
034	Emergent woody vascular plants

1.2 Water typically contains a moderate dissolved solid (0.5–30 ppt) content

Bottom of water column (includes substrates under water columns >25 cm deep)

035	Corral reef
036	Worm reef
037	Mollusk reef
038	Man-made structure (artificial reef)
039	Bedrock (solid rock mass)

040 Boulder (>305 mm)
041 Rubble (152–305 mm)
042 Cobble (64–152 mm)
043 Gravel (2–64 mm)
044 Sand (0.063–2 mm)
045 Mud (<0.063 mm) or organic matter (detritus or sapropel)
046 Submerged algae or moss
047 Submerged rooted vascular plants

Water column (water >25 cm below the surface)
048 Water shallow (<2 m)
049 Water deep (>2 m)

Surface of water column (includes substrates and vegetative cover at shoreline or under shallow water [≤25 cm deep], open water [≤25 cm deep], and types of vegetation extending up to or through surface waters)
050 Artificial (man-made) structures
051 Bedrock (solid rock mass)
052 Boulder (>305 mm)
053 Rubble (152–305 mm)
054 Cobble (64–152 mm)
055 Gravel (2–64 mm)
056 Sand (0.063–2 mm)
057 Mud (<0.063 mm) or organic matter (detritus or sapropel)
058 Aquatic bed—algae, moss, or lichen
059 Rooted herbaceous vegetation
060 Rooted woody vegetation
061 Open water
062 Floating filamentous algae (non-rooted and rooted)
063 Floating non-woody vascular plants (non-rooted)
064 Floating non-woody vascular plants (rooted)
065 Floating woody vascular plants (non-rooted)
066 Floating woody vascular plants (rooted)
067 Emergent non-woody vascular plants
068 Emergent woody vascular plants

2.0 **Non-tidal (riverine, palustrine, lacustrine systems)**

2.1 Temporary waters (water usually present only at periodic intervals throughout the year)
069 Temporary wet areas (rain pools and ponds produced by irregular flooding, artificial catchments, and stock ponds temporarily filled with run-off, irrigation ditches and stream beds with seasonal flows only).

2.2 Permanent waters (water usually present throughout the year)

2.21 Species breeds in coldwater environments. Water temperature at time of breeding may typically be less than 15°C and surrounding climate is characterized with a growing season of 120–170 days with a mean July air temperature <15°C, or a growing season <120 days with a mean July air temperature <21°C.[a]

Bottom of water column (includes substrates under water columns >25 cm deep).
070 Bedrock (solid rock mass)
071 Boulder (>305 mm)
072 Rubble (152–305 mm)
073 Cobble (64–152 mm)
074 Gravel (2–64 mm)
075 Sand (0.063–2 mm)
076 Mud (<0.063 mm) or organic matter (detritus or sapropel)
077 Submerged algae or moss
078 Submerged rooted vascular plants

[a]Definition of coldwater, coolwater, and warmwater environments from McConnell, W. J., E. P. Bergersen, and K. L. Williamson (unpublished data).

Water column (water >25 cm below the surface)

079	Little or no flow (e.g., impoundments, lakes, and ponds), shallow (<2 m)
080	Little or no flow (e.g., impoundments, lakes, and ponds), deep (>2 m)
081	Laminar flow (e.g., run or smooth or slow flow in a channel), shallow (<2 m)
082	Laminar flow (e.g., run or smooth or slow flow in a channel), deep (>2 m)
083	Turbulent flow (e.g., riffle or rapid flow in a channel), shallow (<2 m)
084	Turbulent flow (e.g., riffle or rapid flow in a channel), deep (>2 m)

Surface of water column (includes substrates and vegetative cover at shoreline or under shallow water [≤25 cm deep], open water [≤25 cm deep], and types of vegetation extending up to or through surface waters)

085	Artificial (man-made) structures
086	Bedrock (solid rock mass)
087	Boulder (>305 mm)
088	Rubble (152–305 mm)
089	Cobble (64–152 mm)
090	Gravel (2–64 mm)
091	Sand (0.063–2 mm)
092	Mud (<0.063 mm) or organic matter (detritus or sapropel)
093	Aquatic bed – algae, moss, or lichen
094	Rooted herbaceous vegetation
095	Rooted woody vegetation
096	Open water
097	Floating filamentous algae (non-rooted and rooted)
098	Floating non-woody vascular plants (non-rooted)
099	Floating non-woody vascular plants (rooted)
100	Floating woody vascular plants (non-rooted)
101	Floating woody vascular plants (rooted)
102	Emergent non-woody vascular plants
103	Emergent woody vascular plants

2.22 Species breeds in coolwater environments. Water temperature at time of breeding may frequently be between 15 and 21°C but surrounding climate is characterized with a growing season >170 days with a mean July air temperature <15°C, a growing season of 120–170 days with a mean July air temperature >15°C, or a short growing season <120 days with a mean July temperature >21°C.

Bottom of water column (includes substrates under water columns >25 cm deep)

104	Bedrock (solid rock mass)
105	Boulder (>305 mm)
106	Rubble (152–305 mm)
107	Cobble (64–152 mm)
108	Gravel (2–64 mm)
109	Sand (0.063–2 mm)
110	Mud (<0.063 mm) or organic matter (detritus or sapropel)
111	Submerged algae or moss
112	Submerged rooted vascular plants

Water column (water >25 cm below the surface)

113	Little or no flow (e.g., impoundments, lakes, and ponds), shallow (<2 m)
114	Little or no flow (e.g., impoundments, lakes, and ponds), deep (>2 m)
115	Laminar flow (e.g., run or smooth or slow flow in a channel), shallow (<2 m)
116	Laminar flow (e.g., run or smooth or slow flow in a channel), deep (>2 m)
117	Turbulent flow (e.g., riffle or rapid flow in a channel), shallow (<2 m)
118	Turbulent flow (e.g., riffle or rapid flow in a channel), deep (>2 m)

Surface of water column (includes substrates and vegetative cover at shoreline or under shallow water [≤25 cm deep], open water [≤25 cm deep], and types of vegetation extending up to or through surface waters)

119	Artificial (man-made) structures
120	Bedrock (solid rock mass)
121	Boulder (>305 mm)
122	Rubble (152–305 mm)
123	Cobble (64–152 mm)
124	Gravel (2–64 mm)
125	Sand (0.063–2 mm)
126	Mud (<0.063 mm) or organic matter (detritus or sapropel)
127	Aquatic bed—algae, moss, or lichen
128	Rooted herbaceous vegetation
129	Rooted woody vegetation
130	Open water
131	Floating filamentous algae (non-rooted and rooted)
132	Floating non-woody vascular plants (non-rooted)
133	Floating non-woody vascular plants (rooted)
134	Floating woody vascular plants (non-rooted)
135	Floating woody vascular plants (rooted)
136	Emergent non-woody vascular plants
137	Emergent woody vascular plants

2.23 Species breeds in warmwater environments. Water temperature at time of breeding may typically be >18°C, and surrounding climate is characterized with a growing season >170 days with a mean July air temperature >15°C.

Bottom of water column (includes substrates under water columns >25 cm deep)

138	Bedrock (solid rock mass)
139	Boulder (>305 mm)
140	Rubble (152–305 mm)
141	Cobble (64–152 mm)
142	Gravel (2–64 mm)
143	Sand (0.063–2 mm)
144	Mud (<0.063 mm) or organic matter (detritus or sapropel)
145	Submerged algae or moss
146	Submerged rooted vascular plants

Water column (water >25 cm below the surface)

147	Little or no flow (e.g., impoundments, lakes, and ponds), shallow (<2 m)
148	Little or no flow (e.g., impoundments, lakes, and ponds), deep (>2 m)
149	Laminar flow (e.g., run or smooth or slow flow in a channel), shallow (<2 m)
150	Laminar flow (e.g., run or smooth or slow flow in a channel), deep (>2 m)
151	Turbulent flow (e.g., riffle or rapid flow in a channel), shallow (<2 m)
152	Turbulent flow (e.g., riffle or rapid flow in a channel), deep (>2 m)

Surface of water column (includes substrates and vegetative cover at shoreline or under shallow water [≤25 cm deep], open water [≤25 cm deep], and types of vegetation extending up to or through surface waters)

153	Artificial (man-made) structures
154	Bedrock (solid rock mass)
155	Boulder (>305 mm)
156	Rubble (152–305 mm)
157	Cobble (64–152 mm)
158	Gravel (2–64 mm)
159	Sand (0.063–2 mm)
160	Mud (<0.063 mm) or organic matter (detritus or sapropel)
161	Aquatic bed—algae, moss, or lichen
162	Rooted herbaceous vegetation

163 Rooted woody vegetation
164 Open water
165 Floating filamentous algae (non-rooted and rooted)
166 Floating non-woody vascular plants (non-rooted)
167 Floating non-woody vascular plants (rooted)
168 Floating woody vascular plants (non-rooted)
169 Floating woody vascular plants (rooted)
170 Emergent non-woody vascular plants
171 Emergent woody vascular plants

3.0 **Terrestrial Systems**

3.1 Terrestrial subsurface (to 10 cm below apparent surface)

172 Ground burrow maker
173 Ground burrow user
174 Bank burrow maker
175 Bank burrow user
176 Cave and deep crevice
177 Artificial (man-made) structures such as mine shafts and out buildings where interior use is similar to that in burrows or caves

3.2 Terrestrial surface (from 10 cm below apparent surface to 0.5 m above apparent surface)

178 Salt playas or flats with hydric soils
179 Beaches (mud, sand, or rock) without hydrophytes
180 Marshy areas with hydrophytes but not hydric soils
181 Bare ground (sand to rubble, up to 305-mm particles)
182 Boulder (>305 mm) covered surface
183 Talus—unvegetated
184 Talus—vegetated
185 Cliff—on ledge near valley floor
186 Cliff—in cavity near valley floor
187 Cliff—on ledge near mesa or mountain top
188 Cliff—in cavity near mesa or mountain top
189 Herbaceous litter
190 Woody litter (includes shrub branches, tree branches, and stumps)
191 Grass and grasslike vegetation
192 Forb vegetation
193 Supine or dwarf woody vegetation
194 Cactus stems and pads
195 Artificial (man-made) structures—ground debris and artefacts, bridges, trestles, and rooftops where external use is analogous to that of the horizontal and vertical surface of natural objects

3.3 Shrub strata (from 0.5 to 8.0 m above apparent surface)

196 Canopy of broad-leaved deciduous shrubs
197 Canopy of needle-leaved deciduous shrubs
198 Canopy of broad-leaved evergreen shrubs
199 Canopy of needle-leaved evergreen shrubs
200 Grass and grasslike vegetation (includes bamboo) extending into shrub strata
201 Forb vegetation extending into shrub strata
202 Cactus stems and pads extending into shrub strata
203 Cavity maker—boles within shrub strata
204 Cavity user—boles within shrub strata
205 Artificial (man-made) structures—extending into shrub strata and used in a manner analogous to that of natural vegetation in the shrub strata

3.4 Tree bole

206	Snag – trunk of dead broad-leaved deciduous trees
207	Snag – trunk of dead needle-leaved deciduous trees
208	Snag – trunk of dead broad-leaved evergreen trees
209	Snag – trunk of dead needle-leaved evergreen trees
210	Cavity maker – broad-leaved deciduous trees
211	Cavity maker – needle-leaved deciduous trees
212	Cavity maker – broad-leaved evergreen trees
213	Cavity maker – needle-leaved evergreen trees
214	Cavity user – broad-leaved deciduous trees
215	Cavity user – needle-leaved deciduous trees
216	Cavity user – broad-leaved evergreen trees
217	Cavity user – needle-leaved evergreen trees
218	In or under bark – broad-leaved deciduous trees
219	In or under bark – needle-leaved deciduous trees
220	In or under bark – broad-leaved evergreen trees
221	In or under bark – needle-leaved evergreen trees
222	Snag – cactus bole or stem
223	Cavity maker – cactus bole or stem
224	Cavity user – cactus bole or stem
225	Artificial (man-made) structure – telephone and power poles, chimneys

3.5 Tree canopy

226	Small branches – live broad-leaved deciduous trees
227	Small branches – live needle-leaved deciduous trees
228	Small branches – live broad-leaved evergreen trees
229	Small branches – live needle-leaved evergreen trees
230	Large branches – live broad-leaved deciduous trees
231	Large branches – live needle-leaved deciduous trees
232	Large branches – live broad-leaved evergreen trees
233	Large branches – live needle-leaved evergreen trees
234	Large branches – dead broad-leaved deciduous trees
235	Large branches – dead needle-leaved deciduous trees
236	Large branches – dead broad-leaved evergreen trees
237	Large branches – dead needle-leaved evergreen trees

4.0 **Breeds elsewhere**

238	Vertebrates that feed in one or more strata during at least one season but do not breed in the habitat type

Appendix III

Vertebrate Species Breeding in Southeastern Montana and Northeastern Wyoming Used in the Species-habitat Matrices. (The species in the phenograms of Figs. 9 to 11 can be identified from these numbers.)

AMPHIBIANS

1. Tiger salamander (*Ambystoma tigrinum*)
2. Plains spadefoot toad (*Scaphiopus bombifrons*)
3. Woodhouse's toad (*Bufo woodhousei*)
4. Great plains toad (*Bufo cognatus*)
5. Dakota toad (*Bufo hemiophrys*)
6. Western chorus frog (*Pseudacris triseriata*)
7. Wood frog (*Rana sylvatica*)
8. Northern leopard frog (*Rana pipiens*)
9. Bullfrog (*Rana catesbeiana*)

REPTILES

10. Common snapping turtle (*Chelydra serpentina*)
11. Painted turtle (*Chrysemys picta*)
12. Ornate box turtle (*Terrapene ornata*)
13. Spiny softshell (*Trionyx spiniferus*)
14. Northern earless lizard (*Holbrookia maculata*)
15. Red-lipped prairie lizard (*Sceloporus undulatus*)
16. Northern sagebrush lizard (*Sceloporus graciosus*)
17. Eastern short-horned lizard (*Phrynosoma douglassi*)
18. Northern many-lined skink (*Eumeces multivirgatus*)
19. Plains hognose snake (*Heterodon nasicus*)
20. Western smooth green snake (*Opheodrys vernalis*)
21. Western yellowbelly racer (*Coluber constrictor*)
22. Bullsnake (*Pituophis melanoleucus*)
23. Central plains milk snake (*Lampropeltis triangulum*)
24. Northern redbelly snake (*Storeria occipitomaculata*)
25 Western wandering garter snake (*Thamnophis elegans*)
26. Western plains garter snake (*Thamnophis radix*)
27. Red-sided garter snake (*Thamnophis sirtalis*)
28. Prairie rattlesnake (*Crotalus viridis*)

BIRDS

29. Common loon (*Gavia immer*)
30. Red-necked grebe (*Podiceps grisegena*)
31. Horned grebe (*Podiceps auritus*)
32. Eared grebe (*Podiceps caspicus*)
33. Western grebe (*Aechmophorus occidentalis*)
34. Pied-billed grebe (*Podilymbus podiceps*)
35. Double-crested cormorant (*Phalacrocorax auritus*)
36. Great blue heron (*Ardea herodias*)
37. Black-crowned night heron (*Nycticorax nycticorax*)
38. American bittern (*Botaurus lentiginosus*)
39. Canada goose (*Branta canadensis*)
40. Mallard (*Anas platyrhynchos*)
41. Gadwall (*Anas strepera*)
42. Pintail (*Anas acuta*)
43. Blue-winged teal (*Anas discors*)
44. Green-winged teal (*Anas crecca*)
45. American wigeon (*Anas americana*)
46. Northern shoveler (*Anas clypeata*)
47. Redhead (*Aythya americana*)
48. Canvasback (*Aythya valisineria*)
49. Lesser scaup (*Aythya affinis*)
50. Harlequin duck (*Histrionicus histrionicus*)
51. Ruddy duck (*Oxyura jamaicensis*)
52. Hooded merganser (*Lophodytes cucullatus*)
53. Common merganser (*Mergus merganser*)
54. Turkey vulture (*Cathartes aura*)
55. Goshawk (*Accipiter gentilis*)
56. Sharp-shinned hawk (*Accipiter striatus*)
57. Cooper's hawk (*Accipiter cooperii*)
58. Red-tailed hawk (*Buteo jamaicensis*)
59. Swainson's hawk (*Buteo swainsoni*)
60. Ferruginous hawk (*Buteo regalis*)
61. Golden eagle (*Aquila chrysaetos*)
62. Marsh hawk (*Circus cyaneus*)
63. Osprey (*Pandion haliaetus*)
64. Prairie falcon (*Falco mexicanus*)
65. American kestrel (*Falco sparverius*)
66. Ruffed grouse (*Bonasa umbellus*)
67. Blue grouse (*Dendragapus obscurus*)
68. Sharp-tailed grouse (*Pedioecetes phasianellus*)
69. Sage grouse (*Centrocercus urophasianus*)
70. Ring-necked pheasant (*Phasianus colchicus*)
71. Gray partridge (*Perdix perdix*)
72. Merriam's turkey (*Meleagris gallopavo*)
73. Sandhill crane (*Grus canadensis*)
74. Virginia rail (*Rallus limicola*)
75. Sora (*Porzana carolina*)
76. American coot (*Fulica americana*)
77. Piping plover (*Charadrius melodus*)
78. Killdeer (*Charadrius vociferus*)
79. Mountain plover (*Eupoda montana*)
80. Common snipe (*Capella gallinago*)
81. Long-billed curlew (*Numenius americanus*)
82. Upland sandpiper (*Bartramia longicauda*)
83. Spotted sandpiper (*Actitis macularia*)
84. Willet (*Catoptrophorus semipalmatus*)
85. Marbled godwit (*Limosa fedoa*)
86. American avocet (*Recurvirostra americana*)
87. Wilson's phalarope (*Steganopus tricolor*)
88. Ring-billed gull (*Larus delawarensis*)
89. Common tern (*Sterna hirundo*)
90. Black tern (*Chlidonias niger*)
91. Rock dove (*Columba livia*)
92. Mourning dove (*Zenaida macroura*)
93. Yellow-billed cuckoo (*Coccyzus americanus*)
94. Black-billed cuckoo (*Coccyzus erythropthalmus*)

95. Screech owl (*Otus asio*)
96. Great horned owl (*Bubo virginianus*)
97. Pygmy owl (*Glaucidium gnoma*)
98. Burrowing owl (*Athene cunicularia*)
99. Long-eared owl (*Asio otus*)
100. Short-eared owl (*Asio flammeus*)
101. Saw-whet owl (*Aegolius acadicus*)
102. Poor-Will (*Phalaenoptilus nuttallii*)
103. Common nighthawk (*Chordeiles minor*)
104. Chimney swift (*Chaetura pelagica*)
105. White-throated swift (*Aeronautes saxatalis*)
106. Belted kingfisher (*Megaceryle alcyon*)
107. Common flicker (*Colaptes auratus*)
108. Red-headed woodpecker (*Melanerpes erythrocephalus*)
109. Lewis' woodpecker (*Melanerpes lewis*)
110. Yellow-bellied sapsucker (*Sphyrapicus varius*)
111. Williamson's sapsucker (*Sphyrapicus thyroideus*)
112. Hairy woodpecker (*Picoides villosus*)
113. Downy woodpecker (*Picoides pubescens*)
114. Black-backed three-toed woodpecker (*Picoides arcticus*)
115. Eastern kingbird (*Tyrannus tyrannus*)
116. Western kingbird (*Tyrannus verticalis*)
117. Say's phoebe (*Sayornis saya*)
118. Willow flycatcher (*Empidonax traillii*)
119. Least flycatcher (*Empidonax minimus*)
120. Dusky flycatcher (*Empidonax oberholseri*)
121. Western flycatcher (*Empidonax difficilis*)
122. Hammond's flycatcher (*Empidonax hammondii*)
123. Western wood pewee (*Contopus sordidulus*)
124. Horned lark (*Eremophila alpestris*)
125. Violet-green swallow (*Tachycineta thalassina*)
126. Tree swallow (*Iridoprocne bicolor*)
127. Bank swallow (*Riparia riparia*)
128. Rough-winged swallow (*Stelgidopteryx ruficollis*)
129. Barn swallow (*Hirundo rustica*)
130. Cliff swallow (*Petrochelidon pyrrhonota*)
131. Gray jay (*Perisoreus canadensis*)
132. Steller's jay (*Cyanocitta stelleri*)
133. Black-billed magpie (*Pica pica*)
134. Common raven (*Corvus corax*)
135. Common crow (*Corvus brachyrhynchos*)
136. Pinyon jay (*Gymnorhinus cyanocephalus*)
137. Clark's nutcracker (*Nucifraga columbiana*)
138. Black-capped chickadee (*Parus atricapillus*)
139. Mountain chickadee (*Parus gambeli*)
140. White-breasted nuthatch (*Sitta carolinensis*)
141. Red-breasted nuthatch (*Sitta canadensis*)
142. Brown creeper (*Certhia familiaris*)
143. Dipper (*Cinclus mexicanus*)
144. House wren (*Troglodytes aedon*)
145. Long-billed marsh wren (*Cistothorus palustris*)
146. Canyon wren (*Catherpes mexicanus*)
147. Rock wren (*Salpinctes obsoletus*)
148. Gray catbird (*Dumetella carolinensis*)
149. Brown thrasher (*Toxostoma rufum*)
150. Sage thrasher (*Oreoscoptes montanus*)
151. American robin (*Turdus migratorius*)
152. Hermit thrush (*Catharus guttatus*)
153. Swainson's thrush (*Catharus ustulatus*)
154. Veery (*Catharus fuscescens*)
155. Eastern bluebird (*Sialia sialis*)
156. Mountain bluebird (*Sialia currucoides*)
157. Townsend's solitaire (*Myadestes townsendi*)
158. Golden-crowned kinglet (*Regulus satrapa*)
159. Ruby-crowned kinglet (*Regulus calendula*)
160. Sprague's pipit (*Anthus spragueii*)
161. Cedar waxwing (*Bombycilla cedrorum*)
162. Loggerhead shrike (*Lanius ludovicianus*)
163. Starling (*Sturnus vulgaris*)
164. Solitary vireo (*Vireo solitarius*)
165. Red-eyed vireo (*Vireo olivaceus*)
166. Warbling vireo (*Vireo gilvus*)
167. Orange-crowned warbler (*Vermivora celata*)
168. Yellow warbler (*Dendroica petechia*)
169. Ovenbird (*Seiurus aurocapillus*)
170. Common yellowthroat (*Geothlypis trichas*)
171. Yellow-breasted chat (*Icteria virens*)
172. Wilson's warbler (*Wilsonia pusilla*)
173. American redstart (*Setophaga ruticilla*)
174. House sparrow (*Passer domesticus*)
175. Bobolink (*Dolichonyx oryzivorus*)
176. Western meadowlark (*Sturnella neglecta*)
177. Yellow-headed blackbird (*Xanthocephalus xanthocephalus*)
178. Red-winged blackbird (*Agelaius phoeniceus*)
179. Orchard oriole (*Icterus spurius*)
180. Northern oriole (*Icterus galbula*)
181. Brewer's blackbird (*Euphagus cyanocephalus*)
182. Common grackle (*Quiscalus quiscula*)
183. Brown-headed cowbird (*Molothrus ater*)
184. Western tanager (*Piranga ludoviciana*)
185. Black-headed grosbeak (*Pheucticus melanocephalus*)
186. Lazuli bunting (*Passerina amoena*)
187. Dickcissel (*Spiza americana*)
188. Evening grosbeak (*Hesperiphona vespertina*)
189. Cassin's finch (*Carpodacus cassinii*)
190. House finch (*Carpodacus mexicanus*)
191. Pine grosbeak (*Pinicola enucleator*)
192. Gray-crowned rosy finch (*Leucosticte tephrocotis*)
193. Black rosy finch (*Leucosticte atrata*)
194. Pine siskin (*Carduelis pinus*)
195. American goldfinch (*Carduelis tristis*)
196. Red crossbill (*Loxia curvirostra*)
197. Green-tailed towhee (*Pipilo chlorurus*)
198. Rufous-sided towhee (*Pipilo erythrophthalmus*)
199. Lark bunting (*Calamospiza melanocorys*)
200. Savannah sparrow (*Passerculus sandwichensis*)
201. Grasshopper sparrow (*Ammodramus savannarum*)
202. Baird's sparrow (*Ammodramus bairdii*)
203. Vesper sparrow (*Pooecetes gramineus*)
204. Lark sparrow (*Chondestes grammacus*)
205. Dark-eyed junco (*Junco hyemalis*)

206. Chipping sparrow (*Spizella passerina*)
207. Clay-colored sparrow (*Spizella pallida*)
208. Brewer's sparrow (*Spizella breweri*)
209. White-crowned sparrow (*Zonotrichia leucophrys*)
210. Lincoln's sparrow (*Melospiza lincolnii*)
211. Song sparrow (*Melospiza melodia*)
212. McCown's longspur (*Rhynchophanes mccownii*)
213. Chestnut-collared longspur (*Calcarius ornatus*)

MAMMALS

214. Masked shrew (*Sorex cinereus*)
215. Merriam's shrew (*Sorex merriami*)
216. Little brown myotis (*Myotis lucifugus*)
217. Yuma myotis (*Myotis yumanensis*)
218. Long-eared myotis (*Myotis evotis*)
219. Long-legged myotis (*Myotis volans*)
220. Small-footed myotis (*Myotis leibii*)
221. Silver-haired bat (*Lasionycteris noctivagans*)
222. Big brown bat (*Eptesicus fuscus*)
223. Hoary bat (*Lasiurus cinereus*)
224. Townsend's big-eared bat (*Plecotus townsendii*)
225. Eastern cottontail (*Sylvilagus floridanus*)
226. Nuttall's cottontail (*Sylvilagus nuttallii*)
227. Desert cottontail (*Sylvilagus audubonii*)
228. White-tailed jackrabbit (*Lepus townsendii*)
229. Black-tailed jackrabbit (*Lepus californicus*)
230. Least chipmunk (*Eutamias minimus*)
231. Yellow-bellied marmot (*Marmota flaviventris*)
232. Richardson's ground squirrel (*Spermophilus richardsonii*)
233. Thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*)
234. Spotted ground squirrel (*Spermophilus spilosoma*)
235. Black-tailed prairie dog (*Cynomys ludovicianus*)
236. White-tailed prairie dog (*Cynomys leucurus*)
237. Fox squirrel (*Sciurus niger*)
238. Red squirrel (*Tamiasciurus hudsonicus*)
239. Northern pocket gopher (*Thomomys talpoides*)
240. Plains pocket gopher (*Geomys bursarius*)
241. Olive-backed pocket mouse (*Perognathus fasciatus*)
242. Plains pocket mouse (*Perognathus flavescens*)
243. Silky pocket mouse (*Perognathus flavus*)
244. Hispid pocket mouse (*Perognathus hispidus*)
245. Ord's kangaroo rat (*Dipodomys ordii*)
246. Beaver (*Castor canadensis*)
247. Western harvest mouse (*Reithrodontomys megalotis*)
248. Deer mouse (*Peromyscus maniculatus*)
249. White-footed mouse (*Peromyscus leucopus*)
250. Northern grasshopper mouse (*Onychomys leucogaster*)
251. Bushy-tailed wood rat (*Neotoma cinerea*)
252. Meadow vole (*Microtus pennsylvanicus*)
253. Long-tailed vole (*Microtus longicaudus*)
254. Prairie vole (*Microtus ochrogaster*)
255. Sagebrush vole (*Lagurus curtatus*)
256. Muskrat (*Ondatra zibethicus*)
257. House mouse (*Mus musculus*)
258. Meadow jumping mouse (*Zapus hudsonius*)
259. Porcupine (*Erethizon dorsatum*)
260. Coyote (*Canis latrans*)
261. Red fox (*Vulpes vulpes*)
262. Swift fox (*Vulpes velox*)
263. Black bear (*Ursus americanus*)
264. Raccoon (*Procyon lotor*)
265. Long-tailed weasel (*Mustela frenata*)
266. Mink (*Mustela vison*)
267. Badger (*Taxidea taxus*)
268. Western spotted skunk (*Spilogale gracilis*)
269. Striped skunk (*Mephitis mephitis*)
270. Lynx (*Felis lynx*)
271. Bobcat (*Felis rufus*)
272. Elk (*Cervus elaphus*)
273. Mule deer (*Odocoileus hemionus*)
274. White-tailed deer (*Odocoileus virginianus*)
275. Pronghorn (*Antilocapra americana*)

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A list of current *Special Scientific Report – Wildlife* follows.

225. Scalation of the American Alligator, by Charles A. Ross and Charles D. Roberts. 1979. 8 pp.

(Reports 226 and 227 are in one cover)

226. Waterfowl Status Report, 1975, compiled and edited by James R. Goldsberry, Sharon L. Rhoades, Lonnie D. Schroeder, and Morton M. Smith. 1980. 86 pp.
227. Waterfowl Status Report, 1976, compiled and edited by William W. Larned, Sharon L. Rhoades, and K. Duane Norman. 1980. 88 pp.
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(Reports 236 and 237 are in one cover)

236. Waterfowl Status Report, 1977, compiled and edited by Carey S. Smith, Sharon L. Rhoades, and K. Duane Norman. 1981. 88 pp.
237. Waterfowl Status Report, 1978, compiled and edited by Albert N. Novara, Sharon L. Rhoades, Betty I. Hodges, and K. Duane Norman. 1981. 96 pp.
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241. Residues of DD [illegible] wo Years Following Application, by Charles D. Gish and
242. Changes in Ve [illegible] irie Pothole Region, by Kenneth F. Higgins and William
243. Bibliography o [illegible] S. Wilson and Louis N. Locke. 1982. 10 pp.

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